CTA
Working Paper
16/13

Improving the Evidence Base on Aflatoxin Contamination and Exposure in Africa

Sheila Okoth

Series: Agriculture and nutrition

CTA Working Paper 16/13 | November 2016

Improving the Evidence Base on Aflatoxin Contamination and Exposure in Africa: Strengthening the Agriculture-Nutrition Nexus

Sheila Okoth

University of Nairobi

About CTA

The Technical Centre for Agricultural and Rural Cooperation (CTA) is a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). Its mission is to advance food and nutritional security, increase prosperity and encourage sound natural resource management in ACP countries. It provides access to information and knowledge, facilitates policy dialogue and strengthens the capacity of agricultural and rural development institutions and communities.

CTA operates under the framework of the Cotonou Agreement and is funded by the EU.

For more information on CTA, visit www.cta.int

About the Lead and Contributing Author

Sheila Okoth, the lead author, is Professor of Mycology at the University of Nairobi, a world-class public collegiate university based in Kenya. Professor Okoth has researched fungi and their metabolites for more than 15 years, with special emphasis on toxigenic properties of *Aspergillus* and *Fusarium* species. Sheila is the Vice President of the African Society of Mycotoxicology. For more information on the University of Nairobi, visit www.uonbi.ac.ke

Dr Joyce Mynazi Jefwa is a mycorrhizae and mushroom specialist. Joyce is a senior lecturer in the Department of Biological Science at Pwani University, Kenya.

About the Partnership for Aflatoxin Control in Africa (PACA)

PACA is a flagship programme of the African Union Commission (AUC). Its mission is to support agricultural development, safeguard consumer health and facilitate trade by catalysing, coordinating and increasing effective aflatoxin control along agricultural value chains in Africa.

About CTA Working Papers

CTA's Working Papers present work in progress and preliminary findings and have not been formally peer reviewed. They are published to elicit comments and stimulate discussion. Any opinions expressed are those of the author(s) and do not necessarily reflect the opinions or policies of CTA, donor agencies, or partners. All images remain the sole property of their source and may not be used for any purpose without written permission of the source.

Please address comments on this Working Paper to Judith A. Francis, Senior Programme Coordinator, Science and Technology Policy at CTA.

Contents

List of figures

List of tables

Acronyms

AATF	African Agriculture Technology Foundation
AF-alb	Aflatoxin–albumin
APTECA	Aflatoxin Proficiency Testing and Control in Africa
AUC	African Union Commission
BecA-ILRI	Biosciences eastern and central Africa-International Livestock Research Institute
BMGF	Bill and Melinda Gates Foundation
CIMMYT	International Maize and Wheat Improvement Centre
COMESA	Common Market for Eastern and Southern Africa
CTA	Technical Centre for Agricultural and Rural Cooperation
DRC	Democratic Republic of Congo
DTMA	Drought Tolerant Maize for Africa project
EAC	East African Community
EC	European Commission
ECOWAS	Economic Community of West African States
ELISA	Enzyme-Linked Immunosorbent Assay
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FTA	Free trade area
GAP	Good agricultural practices
GC	Gas Chromatography
GMP	Good manufacturing practices
GST	Glutathione-s-transferase
HBV	Hepatitis B Virus
HCC	Hepatocellular carcinoma
HIV	Human immunodeficiency virus
HPLC	High-Performance Liquid Chromatography

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFMP	Infant formula milk powder
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
ISO	International Organization for Standardization
LP	Locally processed
MBM	Maternal breast milk
MS	Mass Spectrometry
NAFDAC	National Agency for Food and Drugs Administration and Control (Nigeria)
NIR	Near Infrared
PACA	Partnership for Aflatoxin Control in Africa
QuEChERS	Quick, Easy, Cheap, Effective, Rugged, and Safe
REC	Regional economic communities
SADC	South Africa Development Community
TLC	Thin Layer Chromatography
UEMOA	Union Economique et Monẻtaire Quest Africaine
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VCG	Vegetative compatible groups
WHO	World Health Organization

Acknowledgements

This work was supported by the Technical Centre for Agricultural and Rural Cooperation (CTA) and the Partnership for Aflatoxin Control in Africa (PACA). Special mention is made of the role played by Judith Ann Francis, Senior Programme Coordinator, Science and Technology Policy at CTA for reviewing, editing and co-authoring various sections of this report. Dr Joyce Jefwa's contribution as a co-author of the initial report and in researching the food safety and legislative framework is appreciated. The critical and insightful review of early drafts by Dr Amare Ayalew, Programme Manager at PACA, and his technical team added to the precision of the evidence generated. Sincere thanks are extended to the peer reviewers; Dr Martin Epafras Kimanya of the Nelson Mandela African Institution of Science and Technology (NM-AIST) in Tanzania and Dr Owen Fraser, Head of Nestle Quality Assurance Centre in Côte d'Ivoire. The University of Nairobi provided the platform for the literature search and management of funds.

Executive summary

This report reveals that substantial knowledge is available about the aflatoxin challenge that plagues African farmers, other agri-entrepreneurs, and governments. Commissioned by the ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA) in collaboration with the African Union Commission - Partnership for Aflatoxin Control in Africa (PACA), this literature review reveals that a wide range of commodities that are traded nationally, regionally and internationally are contaminated by aflatoxins. African citizens and economies are negatively impacted as a result.

Aflatoxins are a problem for agriculture, health and trade in Africa. At high doses, aflatoxins can cause acute poisoning and death, and at chronic lower-level doses they can cause liver cancer and chronic immunosuppression. They are also associated with kwashiorkor and poor growth in young children. The report shows that aflatoxin exposure in humans and livestock, including farmed fish, is pronounced due to:

- the widespread occurrence of the *Aspergillus* fungi that produce aflatoxins
- the wide range of agro-ecological conditions, temperature and humidity which favour the growth of *Aspergillus flavus* and *Aspergillus parasiticus* and other *Aspegillus* species (*A. flavus* and *A. parasiticus* are the two most economically important species)
- the wide variety of cereals (maize, millet, rice, sorghum, teff, wheat), and other crops (legumes [including groundnuts], roots and tubers [cassava], spices, and tree nuts) that are contaminated in the field or in storage by the *Aspergillus* fungi. The contaminated crops are also used in the production of processed foods and animal feeds, resulting in processed foods (e.g. peanut butter and vegetable oils) and foods of animal origin (e.g. eggs, milk and meat) being contaminated as well
- many aflatoxin-susceptible grains and legumes are essential staple foods for a wide-cross section of African consumers
- a low level of awareness of aflatoxin contamination, the health risks and potential mitigation measures. Low coverage of vaccination against hepatitis B and absence of vaccination against hepatitis A also increase the risk of developing liver cancer
- weak governance and legislative framework, nationally and regionally
- limited human resource capacity and access to up-to-date laboratory infrastructure for monitoring and evaluating levels of contamination and exposure
- numerous unsynergsitic interventions driven by multiple interest groups.

The enabling environment for enhanced aflatoxin control is critical. Developing and implementing policy guidelines and national regulations to govern aflatoxin contamination are pre-requisites for success and will build consumer confidence. Accelerating the harmonisation of relevant policies and regulations within and across regional trading blocks and ensuring alignment, as far as is possible, with those of major international trading partners (e.g. the European Union) will enhance intra- and inter-regional trade and access to international markets. Improving capacity and laboratory infrastructure to ensure conformance to standards will also expand market opportunities for African farmers, traders, processors and other value chain actors. There is need to better coordinate the numerous development and research efforts, promote and share good practice, and mobilise stakeholders (especially farmers and other private sector actors) around a shared agenda for achieving greater impact in controlling aflatoxin.

Since farmers (both crop and livestock) are key stakeholders and the first target group in the aflatoxin control chain, priority should be given to building their capacity for adopting good agricultural practices (GAP) (e.g. selection of suitable varieties, site selection and preparation), improving post-harvest management (including proper drying and moisture control, rapid aflatoxin detection), and implementing good manufacturing practices during storage and distribution. Consumers also need to be made more aware of the health risks posed by exposure to aflatoxin-contaminated food and empowered to demand safe, quality food.

PACA has contributed towards improving the knowledge base by generating country-specific data on the state of aflatoxin contamination and exposure and has developed action plans in selected countries. These home-grown aflatoxin control action plans are in the process of being mainstreamed into national strategies and frameworks in pilot countries. Other activities include: mobilising support for building capacity in aflatoxin testing (efforts of the International Livestock Research Institute (ILRI) Biosciences eastern and central Africa (BeCA) Hub are noteworthy); compiling research and development activities and outputs; promoting good practice in creating databases accessible to stakeholders; and bringing researchers, policymakers, private sector actors and investors/financiers/donors together to identify strategic joint action and develop plans with clear targets and deadlines for aflatoxin control in Africa. CTA will continue to partner with PACA and other key African and international public and private sector partners in continued efforts to control aflatoxin contamination in Africa for enhanced agricultural performance, agri-business development, trade, nutrition and health.

1.0 Introduction

1.1 Aflatoxins: An overview

Aflatoxins are a group of mycotoxins that are classified in two broad sub-groups; the difurocoumarocyclopentenone series and the difurocoumarolactone series (Table 1). The major types of aflatoxins are; AFB_1, AFB_2, AFG_1 and AFG_2. In human beings and other animals, aflatoxins are reported to be carcinogenic, mutagenic and immunosuppressive. At high enough exposure levels, they can cause acute toxicity and, potentially, death in mammals, birds and fish. They display potency of toxicity, carcinogenicity and mutagenicity in the order of $AFB_1 > AFG_1 > AFB_2 > AFG_2$ as illustrated by their LD_{50} (lethal dose that causes the death of 50% of subjects) values for day-old ducklings (Carnaghan, 1965; Kraybill, 1970; Jewers, 2015). Day-old ducklings are the most sensitive animals to aflatoxins. The minor aflatoxins have been described as mammalian biotransformation products of the major metabolites.

Aflatoxins are produced by *Aspergillus species* which are soil-borne fungi that are found worldwide (Table 2). About 20 *Aspergillus sp* assigned to three sections – *Flavi, Nidulantes* and *Ochraceorosei* – have been reported to produce aflatoxins (Baranyi *et al.,* 2013; Table 2). Most species produce B-type aflatoxins although species related to *A. parasiticus* and *A. nomius* are usually able to produce G-type aflatoxins.

The most economically important species are *A. flavus* and *A. parasiticus.* Both are saprophytic (living on dead or decaying material) during most of their life-cycle. They are also plant pathogens and are found on a wide variety of crops produced in Africa including cereals, legumes, oilseeds, roots and tubers, spices, and tree nuts.

A. flavus is divided into two morphotypes, the S and L strains (Cotty, 1989). Each morphotype is divided into many vegetative compatible groups (VCGs) that limit gene flow among dissimilar individuals (Papa, 1986; Bayman and Cotty, 1991). Both morphotypes and VCGs differ in many characteristics such as aflatoxin-producing ability (Bayman and Cotty 1993; Cotty 1997; Cotty and Cardwell, 1999). The S strain produces, on average, much higher aflatoxin concentrations than the L strain (Okoth *et al.,* 2012). Some isolates produce no aflatoxins at all and are termed atoxigenic (Cotty, 1990). Aflatoxin-producing ability tends to be similar among members of the same VCG (Bayman and Cotty 1993; Ehrlich and Cotty, 2004). The molecular basis for atoxigenicity is known in some cases (Ehrlich and Cotty, 2004; Chang *et al.,* 2005).

In 1993, the International Agency for Research on Cancer classified aflatoxin B_1 as a human Class 1 carcinogen (IARC, 2002). Aflatoxin B_1 is the most potent natural carcinogen known (Squire, 1981; IARC, 2012a) and is usually the major aflatoxin produced by toxigenic *A. flavus* strains.

Table 1: Major aflatoxins and the metabolites

Difuranocoumarins	Type of aflatoxins	Metabolites
Difurocoumarocyclopentenone series	Aflatoxin B_1 (AFB_1)	
	Aflatoxin B_2 (AFB_2)	
	Aflatoxin B_{2a} (AFB_{2a})	
	Aflatoxin M_1 (AFM_1)	Metabolite of aflatoxin B_1 in humans and animals and comes from a mother's milk
	Aflatoxin M_2 (AFM_2)	Metabolite of aflatoxin B_2 in milk of cattle fed on contaminated foods
	Aflatoxin M_{2A} (AFM_{2A})	Metabolite of AFM_2
	Aflatoxicol (AFL)	Metabolite of AFB_1
	Aflatoxicol M_1	Metabolite of AFM_1
Difurocoumarolactone series	Aflatoxin G_1 (AFG_1)	
	Aflatoxin G_2 (AFG_2)	
	Aflatoxin G_{2A} (AFG_{2A})	Metabolite of AFG_2
	Aflatoxin GM_1 ($AFGM_1$)	
	Aflatoxin GM_2 ($AFGM_2$)	Metabolite of AFG_2
	$AFGM_{2A}$	Metabolite of $AFGM_2$
	Aflatoxin B_3 (AFB_3)	
	Parasiticol (P)	
	Aflatrem	
	Aspertoxin	
	Aflatoxin Q_1 (AFQ_1)	Major metabolite of AFB_1 in in-vitro liver preparations of other higher vertebrates

Source: Adapted from Heathcote and Dutton, 1969; Bbosa *et al.,* 2013

Table 2: *Aspergillus* species - Type of aflatoxins and other mycotoxins produced and their occurrence

Species by section	Occurrence – countries where aflatoxins are commonly found	Type of aflatoxin produced	Other mycotoxins	References
Aspergillus* section – *Flavi				
A.arachidicola	Argentina, Brazil	Aflatoxins B_1, B_2 and G_1, G_2	Kojic acid, aspergillic acid	Pildain *et al.*, 2008; Calderari *et al.*, 2013
A.bombycis	Japan, Indonesia, Brazil	Aflatoxins B_1, B_2 and G_1, G_2	Kojic acid, aspergillic acid	Peterson *et al.*, 2001; Okano *et al.*, 2012; Calderari *et al.*, 2013
A.flavus	Worldwide	Aflatoxins B_1, B_2	Cyclopiazonic acid, kojic acid, aspergillic acid	Varga *et al.*, 2009
A.minisclerotigenes	Argentina, USA, Australia, Nigeria, Portugal, Benin, Morocco, Algeria, Kenya	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, kojic acid, aspergillic acid	Pildain *et al.*, 2008; Guezlane-Tebibel *et al.*, 2012; Probst *et al.*, 2012; Soares *et al.*, 2012; El Mahgubi *et al.*, 2013; Moore *et al.*, 2013; Probst *et al.*, 2014
A.nomius	USA, Japan, Thailand, India, Brazil, Hungary, Serbia	Aflatoxins B1, B_2 and G_1, G_2	Kojic acid, aspergillic acid, tenuazonic acid	Kurtzman *et al.*, 1987; Olsen *et al.*, 2008; Manikandan *et al.*, 2009; Okano *et al.*, 2012; Calderari *et al.*, 2013; unpublished observations
A.novoparasiticus	Columbia, Brazil	Aflatoxins B_1, B_2 and G_1, G_2	Kojic acid	Gonçalves *et al.*, 2012
A.parasiticus	USA, Japan, Australia, Brazil, India, South America, Uganda, Portugal, Italy, Serbia	Aflatoxins B_1, B_2 and G_1, G_2	Kojic acid, aspergillic acid	Varga *et al.*, 2009; Soares *et al.*, 2012; Baquião *et al.*, 2013
A.parvisclerotigenus	Nigeria	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, kojic acid	Geiser *et al.*, 2000; Frisvad *et al.*, 2005

Species by section	Occurrence – countries where aflatoxins are commonly found	Type of aflatoxin produced	Other mycotoxins	References
A.pseudocaelatus	Argentina	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, kojic acid	Varga *et al.*, 2011
A.pseudonomius	USA	Aflatoxin B_1	Kojic acid	Varga *et al.*, 2011
A.pseudotamarii	Japan, Argentina, Brazil, India	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, kojic acid	Ito *et al.*, 2001; Baranyi *et al.*, 2013; Calderari *et al.*, 2013
A.togoensis	Central Africa	Aflatoxin B_1	Sterimatocystin	Wicklow *et al.*, 1989; Rank *et al.,* 2011
A.transmontanensis	Portugal	Aflatoxins B1, B_2 and G_1, G_2	Aspergillic acid	Soares *et al.*, 2012
A.mottae	Portugal	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, Aspergillic acid	Soares *et al.*, 2012
A.sergii	Portugal	Aflatoxins B_1, B_2 and G_1, G_2	Cyclopiazonic acid, Aspergillic acid	Soares *et al.*, 2012
Aspergillus* section - *Ochraceorosei				
A.ochraceoroseus	Côte d'Ivoire	Aflatoxin B_1	Sterigmatocystin	Frisvad *et al.*, 1999
A.rambellii	Côte d'Ivoire	Aflatoxin B_1	Sterigmatocystin	Frisvad *et al.*, 2005
Aspergillus* section - *Nidulantes	Ecuador	Aflatoxin B_1	Sterigmatocystin, terrein	Frisvad and Samson, 2004; Frisvad *et al.*, 2005
A.astellatus (=*Emericella olivicola*)	Italy	Aflatoxin B_1	Sterigmatocystin, terrein	Zalar *et al.*, 2008
A.venezuelensis (=*Emericella venezuelensis*)	Venezuela	Aflatoxin B_1	Sterigmatocystin, terrein	Frisvad and Samson, 2004

Source: Adapted from Baranyi *et al.*, 2013

Structure of aflatoxins

Aflatoxins have closely related structures and form a unique group of highly-oxygenated heterocyclic difuranocoumarin compounds. The compound is made up of five rings, having a furofuran moiety (rings B and C), an aromatic six-membered ring (A), a six-membered lactone ring (D), and either a five-membered pentanone or a six-membered lactone ring (E) (Figure 1 and Figure 2). AFM_1 and AFM_2 are hydroxylated products of aflatoxins AFB_1 and AFB_2, respectively, which bear a hydroxyl group at the junction of the two furan rings (Schuda, 1980). The minor aflatoxins have a hydroxyl group instead of a carbonyl group at ring E (AFR_0,

$AFRB_{1,}$ $AFRB_2$ and AFH_1). In others, the D-ring (AFB_1, $AFRB_2$) or the E-ring (AFB_3) is opened (Figure 2). Other structural analogs (similar molecular structure) include AFP_1 and $AFQ_{1,}$ which are AFB_1 metabolites found in urine and liver of rhesus monkeys, respectively (Dalezios *et al.,* 1971; Masri *et al.,* 1974; Sid *et al.,* 1974).

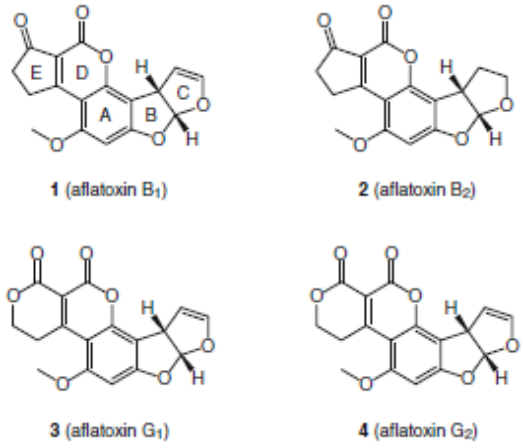

Figure 1: Chemical structure of major aflatoxins

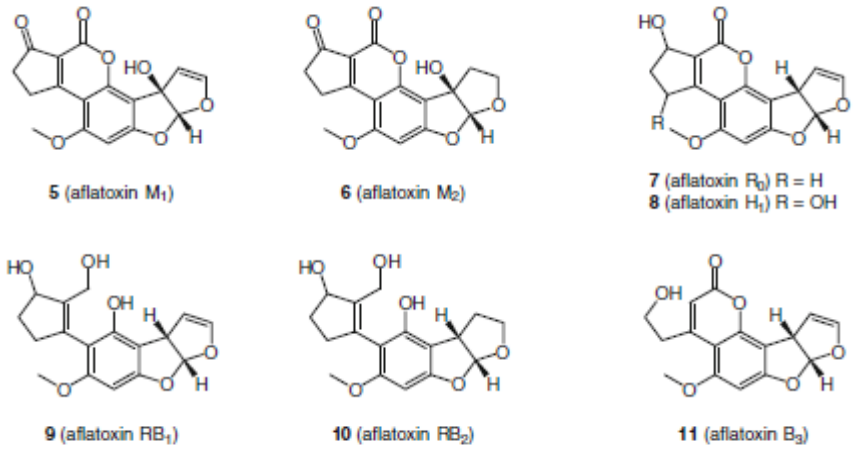

Figure 2: Chemical structure of other selected aflatoxins

Physical and chemical properties of aflatoxins

The reactions of aflatoxins to various physical conditions and reagents have been studied extensively to determine the utility of such reactions in the detoxification of aflatoxin-contaminated material. Aflatoxins are colourless to pale-yellow crystals that fluoresce intensively in ultraviolet light, emitting blue (AFB_1 and AFB_2) or green (AFG_1) and green-blue (AFG_2) fluorescence from which the designations B and G were derived, or blue-violet fluorescence (AFM_1). Aflatoxins are very slightly soluble in water (10–30 µg/ml), insoluble in non-polar solvents, and freely soluble in moderately polar organic solvents such as methanol, chloroform, acetone, acetonitrile and dimethyl sulfoxide (Cole and Cox, 1981). Their melting points are shown in Table 3.

Table 3: Physical properties of aflatoxins

Aflatoxin	Molecular formula	Molecular weight	Melting point (°C)
B_1	$C_{17}H_{12}O_6$	312	268–269
B_2	$C_{17}H_{14}O_6$	314	286–289
G_1	$C_{17}H_{12}O_7$	328	244–246
G_2	$C_{17}H_{14}O_7$	330	237–240
M_1	$C_{17}H_{12}O_7$	328	299
M_2	$C_{17}H_{14}O_7$	330	293
B_{2A}	$C_{17}H_{14}O_7$	330	240
G_{2A}	$C_{17}H_{14}O_8$	346	190

Source: Adapted from O'Neil *et al.,* 2001

Aflatoxins are unstable; to ultraviolet light in the presence of oxygen, to extremes of pH (<3, >10) and to oxidising agents such as sodium hypochlorite, potassium permanganate, chlorine, hydrogen peroxide, ozone and sodium perborate. Aflatoxins are also degraded by reaction with ammonia, various amines and sodium hypochlorite. In a dry state, aflatoxins are stable to heat, up to the melting point. Aflatoxins are very stable and may survive quite severe processes.

A. flavus and A. parasiticus are semithermophilic (tolerant to relatively high temperatures) and semixerophytic (tolerant to arid conditions), growing at temperatures from 12 to 48°C and at water potentials as low as -35 megapascals (Kaushal and Bhatnager, 1998). The optimum temperature for growth is 25–42°C. Under conditions of high temperature and low water activity associated with drought, they become very competitive and may become the dominant fungal species in the soil. These two factors, more than any other, contribute to the epidemiology of these two fungi. The optimum temperature for biosynthesis of aflatoxins ranges between 28–35°C. Higher temperatures inhibit biosynthesis (O'Brian *et al*., 2007; Yu *et al*., 2011). Conditions in Africa are therefore ideal, favouring the growth of these two species and contamination of commodities across the continent.

1.2 Aflatoxin toxicity

Aflatoxin contamination has been reported in a wide range of commodities grown and consumed in Africa: cereals (maize, pearl millet, rice, sorghum, teff, wheat); legumes and oilseeds (groundnuts and peanuts, soybean, sunflower, cottonseed); root and tuber crops; spices (black pepper, chillies, coriander, ginger, turmeric) and tree-nuts (almonds, coconut, pistachio, walnuts); and several vegetables, fruits and even crops such as coffee, cocoa, tea and sugarcane (Sripathomswat and Thasnakom, 1981; Fukal *et al*., 1987; Imwidthaya *et al*., 1987; Juan-Lopez *et al*., 1995; Vinitketkumnuen *et al*., 1997; Vrabcheva, 2000; Reddy *et al*., 2001; Thuvander *et al*., 2001). Aflatoxin contamination occurs at every stage of the supply chain, from pre-production to post-harvesting, marketing and distribution. Aflatoxin accumulation during post-harvesting is a particular challenge for Africa (Miller, 1995; Bankole and Adebanjo, 2003). Once contaminated at any stage in the value chain, commodities remain contaminated throughout all further stages of the chain.

Aflatoxicosis is the poisoning that results from ingesting aflatoxins, although exposure also occurs through dermal (skin) and inhalation routes. Two forms of aflatoxicosis have been identified: the first is acute severe intoxication, which results in liver damage and subsequent illness or death, and the second is chronic sub-symptomatic exposure. A review of the literature across all *Aspergillus* species provides clear evidence that the age of the victim and the dose and duration of exposure to aflatoxin have a major effect on toxicology and cause a range of consequences. While large doses lead to acute illness and death, usually due to liver cirrhosis, chronic sub-lethal doses have nutritional and immunological consequences. All doses have a cumulative effect on the risk of cancer.

Susceptibility to aflatoxin poisoning can be divided into three categories: those with a lethal dose that causes the death of 50% of subjects (LD_{50}) of 1 mg/kg body weight (bwt) or less; those with an LD_{50} of 10 mg/kg bwt or more; and others that are resistant (Schoental, 1967). Dogs, turkey, ducklings, cats and rabbits are highly susceptible animals (Raney *et al.,* 1992; Agag, 2004; Dereszynski *et al.,* 2008). The acute lethal dose of AFB_1 in humans is estimated at 3 mg/kg bwt (Hsieh *et al.,* 1977), a value similar to that of rats (Newberne and Butler, 1969; Heathcote and Hibbert, 1978; Eaton and Heinonen, 1997). Similar pathologic findings have been reported in humans and rats (Serck-Hanssen, 1970; Krishnamachari *et al*., 1975; Ngindu *et al*., 1982; Chao *et al*., 1991). Deaths have been reported mostly in humans, poultry, ducklings and dogs, in selected African countries. Human deaths have been linked primarily to the consumption of contaminated maize in Kenya and to a lesser extent due to the consumption of contaminated cassava in Uganda. More recently, deaths have been linked to consumption of contaminated cereals in Tanzania. It is also likely that many aflatoxin-related fatalities go unreported in Africa due to lack of capacity for testing the toxins.

1.3 Baseline information: Why this study?

Aflatoxins have gained increased recognition in Africa as more research reveals the negative impacts on health, food security and trade. Though produced in small quantities, the ease with which these highly potent, carcinogenic metabolites permeate African farmers' fields, is of grave concern. Most aflatoxin-susceptible commodities produced in Africa do not meet internationally accepted standards, (United States Food and Drugs Administration (FDA), international Codex Alimentarius limits, and European Union (EU) regulations). The contaminated produce is often rejected by major buyers, processors and traders and by international regulatory agencies before entry in key export markets. High consumption of aflatoxin-susceptible commodities in Africa is compounded because rejected produce that does not meet international standards enters African food and feed value chains, leading to increased risk of exposure to the toxins. Chronic exposure to aflatoxins contributes to the increased incidence and severity of many infectious and non-infectious diseases. Extended exposure is implicated in: immunodeficiency and immunosuppression; stunting and kwashiorkor and an interference with the metabolism of micronutrients in children; and liver cancer, especially in people with hepatitis B or C, or liver disease.

Absence of legislation in several African countries and limited capacity for enforcement where they do exist, do not only put consumers and value chain actors at risk, they limit intra-regional and international trade and do harm to businesses and economies. The extent of the problem, level of contamination and exposure is also under-reported, under-estimated and under-costed, hence compiling baseline information and existing knowledge (on occurrence,

management strategies, economic evaluation, exposure patterns and regulatory frameworks and capacities) can support efforts to:

- undertake risk assessments to identify gaps and design risk management strategies to improve processes to better formulate and implement appropriate control measures and set new research and legislative agendas
- support a more concerted collaborative approach among key partners (including governments, farmers and other private sector actors and knowledge institutes) for effectively managing aflatoxin contamination and reducing risks to human health (especially children under five) and trade (domestic, regional, international).

This study, which is based on available literature on Aflatoxin contamination across major value chains in Africa, was commissioned by the ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA) in collaboration with the Partnership for Aflatoxin Control in Africa (PACA). It complements the achievements that PACA has made in building an evidence base to inform policies and programmes for effectively managing aflatoxin contamination in Africa. It will also serve as a basis for facilitating more focused interventions including better coordinated research, education, training, agribusiness development, policy harmonisation and implementation. Building new and strengthening existing strategic partnerships towards a more holistic and integrated approach will contribute to achieving greater impact in controlling aflatoxin contamination in Africa.

2.0 Aflatoxin exposure and contamination of food and feed

This section presents available information on aflatoxin contamination of food and feed, and exposure levels in Africa. There is no comprehensive data set from which to evaluate the prevalence of exposure of humans in Africa and other developing countries. However, likely exposure could be estimated by collating the following:

- reports of acute poisoning incidences
- post-mortem reports in which the toxin has been measured in organs
- reports on contamination in foods sampled from households and markets
- reports on direct measurements of human biological exposure to aflatoxin.

Presence of aflatoxins in agricultural commodities (food and feed) suggests that chronic exposure is a possibility. Whether or not consumption of any particular commodity represents a risk factor is partly determined by how susceptible the commodity tends to be and the amount consumed daily. In most parts of Africa, evaluation of exposure in humans and animals have been reported using data from analysis of aflatoxins in food and feed samples collected from farms, markets, mills and stores. The most reliable measure of exposure, however, may be through analysis of samples of prepared meals because grains are normally sorted, though in varying degrees, to remove kernels that are considered unfit to eat.

Quantification of aflatoxins in food may not give exact exposure levels as the amount of aflatoxins present in raw foods may not be the same as that ingested. Some may be lost through processing and – in some cases – the interaction with other food components may affect bioavailability and hence the systemic dose of aflatoxins. The use of biological markers in epidemiological studies on dietary exposure to aflatoxins has enabled progress beyond the determination of levels in food and feeds.

2.1 Exposure assessment applying biomarkers

Albumin is the only serum protein that binds AFB_1 to form a high level of adducts in rats (Skipper *et al.,* 1985), while haemoglobin binds AFB_1 in a very low yield (Tannenbaum and Skipper, 1984). Moreover, albumin is readily extracted from human blood and provides a relatively non-intrusive measure of the biologically effective dose of ingested AFB_1 (Wild *et al.,* 1990). Identification of the metabolic fate of aflatoxins has provided a more authentic tool for exposure studies from the initial simple detection of free aflatoxins to a more reliable AF-alb adduct (Hendrickse *et al.,* 1982; Tsuboi *et al.,* 1984). The aflatoxin, which binds to albumin, can be AFB_1 and AFG_1 but not AFB_2 and AFG_2, which can be metabolised to 8, 9-epoxide (Egal *et al.,* 2005). However, the AF-alb adduct levels should be regarded as a measure of the AFB_1 levels ingested, due to the fact that the AFG_1 presence in the contaminated food is less prevalent.

The molecular markers developed and applied for aflatoxin analysis include the AFB_1 metabolites and AFB_1 macromolecular adducts. These involve AFM_1 and AFB_1-N_7-guanine in urine, as well as AFB_1-albumin adducts in serum (Wang *et al.,* 2001). The latter adduct is considered to better reflect the longer term intake of AFB_1 based on the longer half-life of albumin in humans (30–60 days) compared to urinary metabolites (Sabbioni *et al.,* 1987; Groopman *et al.,*1994; Williams, 2004). The AF-alb adduct, as a biomarker, is more stable and fluctuates less compared with urinary excretion of aflatoxin metabolites over the same period of time (Wild *et al.,* 1992; Groopman *et al.,* 1994). It has thus been considered to have greater value as a biomarker and has been applied in epidemiological studies on human aflatoxin exposure in different countries (Wild *et al.,* 1990; Wild *et al.,* 1993). This approach may be useful for rapid screening of samples for acute exposures and it also reflects chronic exposure that is not available from other markers such as the aflatoxin-N_7-guanine adduct in urine.

Use of genetic markers to study epidemiology on dietary exposure to aflatoxins has been explored. The association between peanut butter intake as a source of aflatoxins and the gene for glutathione-s-transferase (GST) M_1 ($GSTM_1$) genotype in the etiology of the most common form of liver cancer, hepatocellular carcinoma (HCC) has been investigated in Sudan (Omer *et al.,* 2001). $GSTM_1$ is used as a genetic marker for cancer risk with regard to the homozygous deletion of the gene ($GSTM_1$ null) leading to a lack of corresponding enzymatic activity. The GST enzymes are involved in detoxification of several potentially carcinogenic compounds. The results showed that there was a positive association between peanut butter intake, a humid storage system, HCC incidence and $GSTM_1$ null genotype.

Biomarker studies in Africa

Surveys on aflatoxin exposure using biomarkers in Africa show that 85–100% of children have either detectable levels of serum AF-alb or urinary aflatoxins and high exposure levels of AFB_1 and AFM_1 in human milk (Tables 4, 5 and 6). This is exacerbated by the confirmation of multiple mycotoxin exposure (Jonsyn *et al.,* 1995; Abia *et al.,* 2013; Ezekiel *et al.,* 2014). Aflatoxin exposure begins from utero and continues in the post-natal period through breast-feeding. Cord blood samples in Ghana, Kenya, Nigeria and Sudan – collected from infants whose mothers had aflatoxins in their blood at the time of delivery – tested positive for aflatoxins (Maxwell *et al.,* 1989).

The highest levels of aflatoxin exposure observed worldwide using aflatoxin-albumin adducts

have been in West African countries. Children in Benin and Togo have exceptionally high aflatoxin exposure, with some individual levels of AF-alb greater than 1,100 pico gram (pg) aflatoxin-lysine equivalents/mg albumin (Gong *et al.*, 2002; Gong *et al.*, 2003; Gong *et al.*, 2004). The exposure is widespread (99%) and associated with child stunting, child mortality, immune suppression and childhood neurological impairment. Seasonal and geographical differences in aflatoxin exposure are also reported within Benin, Egypt, The Gambia and Senegal with serum levels higher during the dry seasons compared to wet seasons (Turner *et al.,* 2000; Gong *et al.,* 2004; Polychronaki *et al.,* 2007; Watson *et al.,* 2015). A cross-sectional serosurvey in Kenya confirmed regional influence on exposure patterns (Yard *et al.*, 2013). In this study, 600 serum specimens from the 2007 Kenya AIDS Indicator Survey – a nationally representative cross-sectional serosurvey – were analysed for aflatoxin levels. Seventy-eight percent of the sampled group was exposed to aflatoxins and the exposure varied by province; it was highest in Eastern (median = 7.87 pg/mg albumin) and Coast (median = 3.70 pg/mg albumin) provinces, and lowest in Nyanza (median = < limit of detection [LOD]) and Rift Valley (median = 0.70 pg/mg albumin) provinces. Sex, age group, marital status, religion and socioeconomic characteristics did not influence exposure. Although Kenya has experienced multiple aflatoxicosis outbreaks as previously mentioned and often resulting in fatalities, the extent of exposure in the country has, for a long time, remained unknown.

Several studies have reported correlation between demographic factors and aflatoxin exposure. In Benin, Ghana, Kenya and Togo, age, sex, socioeconomic status and agro-ecological zone and weaning status was significantly associated with aflatoxin-albumin concentration (Gong *et al.*, 2002; Jolly *et al.,* 2006; Leroy *et al.,* 2015). There is also a correlation between AFM_1 in human milk, AFB_1 in sampled food and socioeconomic status of mothers in Nigeria (Adejumo *et al.*, 2013). Low-income mothers were vulnerable to aflatoxins. Biomarkers in urine, have also shown that rural populations were more exposed to several mixtures of mycotoxins in Nigeria (Ezekiel *et al.*, 2014). Similar results on the influence of socio-economic status on exposure pattern to aflatoxins were reported from a longitudinal evaluation of two cohorts in southwestern Uganda (Kang *et al.*, 2015). From the 713 archived (between 1989 and 2010) serum samples from human immunodeficiency virus (HIV)-seronegative participants, 90% of samples were positive for AFB-Lys. There existed a correlation between the adduct levels and residential areas and occupations from further analysis of one of the cohorts sampled four times from 1999 to 2013 (Table 4). The exposure, however, did not vary by demographic parameters such as sex, age group and education level. Although a link between aflatoxins and hepatoma was suggested decades ago in Uganda (Alpert *et al*., 1968; Serck-Hanssen, 1970; Alpert *et al*., 1971), only a few other human exposure studies have been assessed in Uganda: a pilot investigation in a small number of children (Wild *et al.,* 1990) and a pilot study (Asiki *et al.,* 2014). A study from Ghana revealed that all of its participants were exposed to aflatoxins and that the exposure was very high among HIV-infected pregnant and early postpartum women. Serum levels were twice as high in HIV-infected women than in uninfected women and these high levels increased dramatically during pregnancy and early postpartum (Natamba *et al*., 2016).

Aflatoxins have been implicated in the pathogenesis of kwashiorkor, a severe manifestation of protein energy malnutrition in children, since the 1980's (Hendrickse, 1984; Hendrickse, 1991). Though the mechanisms underlying this relationship is still unclear, studies in Africa (Ghana, Kenya, Liberia, Nigeria, South Africa, Sudan, Zimbabwe) have detected aflatoxins most frequently and at high concentrations in the sera and liver of children with kwashiorkor

who conversely showed aflatoxins least frequently in their urine and in concentrations that were disproportionately lower compared to sera/urine aflatoxin levels in other groups (Hendrickse *et al*., 1982; Lamplugh *et al.,* 1982; De Vries *et al.,* 1986; De Vries *et al.*, 1990; Ramjee *et al.,* 1991; Oyelami *et al.*, 1998; Onyemelukwe *et al.,* 2012; Castelino *et al.,* 2015). Oyelami *et al*., (1997) detected aflatoxins in autopsies of lung specimens from children who died from kwashiorkor in Nigeria. These findings indicate altered aflatoxin metabolism in kwashiorkor, supporting existence of a relationship that is further strengthened by a similar geographical distribution of kwashiorkor and aflatoxin presence in food and the similarities of the metabolic disturbance induced by both in animals. Synergisms of kwashiorkor and aflatoxin in causing intestinal function damage, reduced immune function and impaired liver function, are suggested hypotheses.

Table 4: Human exposure to aflatoxins in Africa – results from biomarker studies

Country	**Subject**	**Frequency of aflatoxin-positive samples (%)**	**Concentration of aflatoxin albumin levels (AFB_1-lysine equivalent pg/mg albumin)**	**Remarks**	**References**
Benin and Togo	Children (9 months to 5 years)	99	5–1,064 (mean 32.8)	Greater in fully-weaned children	Gong *et al.,* 2002; Gong *et al.*, 2003; Gong *et al.*, 2004
Egypt	Pregnant women	35	Mean 4.9	Co-exposure	Piekkola *et al.,* 2012
Egypt and Guinea	Infants		Aflatoxin B_1, B_2, G_1, G_2, M_1, M_2, B_{2a}, G_{2a}, B_3, GM_1, and P as well as aflatoxicol		Hatem *et al.*, 2005; Polychronaki *et al.*, 2008
Guinea	Adult male	> 90	nd–385	Co-exposure of aflatoxin and hepatitis B or C viruses	Diallo *et al.,* 1995
The Gambia	Children (3–4 years)	100	2.2–459	Daily consumption of food with > 100 ppb of aflatoxins	Turner *et al.*, 2000
The Gambia	Children (6–9 years)	93	5–456		Turner *et al.*, 2003
The Gambia	Adults	99	5% >100		Wild and Hall, 2000

Country	Subject	Frequency of aflatoxin-positive samples (%)	Concentration of aflatoxin albumin levels (AFB_1-lysine equivalent pg/mg albumin)	Remarks	References
The Gambia	Maternal blood at pregnancy Cord blood Infants (16 weeks		4.8–260.8 5–30.2 5–189.6	Effect on growth	Turner *et al.*, 2007
The Gambia	Children (3–4 years)	95	2.2–250.4		Wild *et al.,* 1993
The Gambia	Children	100	up to 720	Influence of ethnicity and villages	Allen *et al.,*1992
The Gambia, Kenya	Adults	100	7–338		Wild *et al.,* 1990
Ghana	Pregnant women *During pregnancy* HIV-uninfected HIV-infected *Postpartum* HIV-uninfected HIV-infected	100	 1.2 (±0.08) 1.91 (±0.12) 1.15 (±0.13) 3.8 (±0.19)	High levels of aflatoxins in HIV-positive women increased as pregnancy progressed	Natamba *et al.,* 2016
Ghana	Adults		0.12–3	Influence of demographic factors	Jolly *et al.*, 2006
Kenya	Women	100	7.47	4.7–7.1 times higher in poor compared to the best-off women	Leroy *et al.,* 2015
Sierra Leone	Cord blood during pregnancy Maternal blood at delivery	58 75		Co-occurrence	Jonsyn *et al.,* 1994
Tanzania	Children (12–22 months)	84	2.8–652	Greater in fully-weaned children	Shirima *et al.*, 2013; Shirima *et al.*, 2015

Country	Subject	Frequency of aflatoxin-positive samples (%)	Concentration of aflatoxin albumin levels (AFB_1-lysine equivalent pg/mg albumin)	Remarks	References
Uganda 1989–2010 1999–2013		 90 93	 0.4–168 (mean 1.58) 0.4–122.5 (mean 1.18)		Kang *et al.*, 2015

Table 5: Human exposure to aflatoxins in Africa – results from urinary biomarker studies

Country	Subject	Frequency of aflatoxin-positive samples (%)	Contamination rate/ concentration (AFM_1)	Remarks	References
Cameroon	Adults (83% HIV-positive)	83	Detected	Co-exposure	Abia *et al.*, 2013
Cameroon	Kwashiorkor Marasmic Kwashiorkor control	Male 44, female 43, Male 60, female 33, Male 15, female 6.3	0.109–2.84 µg/l 0.109–0.864 µg/l 0.007–0.15 µg/l		Tchana *et al.,* 2010
Egypt	Pregnant women	48	19.7 pg/mg	Co-exposure	Piekkola *et al.*, 2012
Egypt and Guinea	Infants		Aflatoxin B_1, B_2, G_1, G_2, M_1, M_2, B_{2a}, G_{2a}, B_3, GM_1, P, aflatoxicol		Hatem *et al.*, 2005; Polychronaki *et al.*, 2008
Ghana	Adults		Non-detectable to 11,562.36 pg/mg	Peanut and maize consumption	Jolly *et al.*, 2006
Ghana	Children	100	24.7–8368.9 pg/mg	Weaning food	Kumi *et al.,* 2015
Nigeria	Children, adolescents, adults	50.8	Detected in samples from all age categories	Chronic lifetime exposure	Ezekiel *et al.*, 2014
Sierra Leone	Infants (urine, serum, stool)	100, 94, 94			Jonsyn *et al.,* 1999
Sierra Leone	Adults	98		Co-exposure	Jonsyn-Ellis *et al.,* 2000
South Africa	Adults	0	Not detected	Co-exposure	Shephard *et al.*, 2013

Table 6: Aflatoxin levels (AFM_1) in human milk in Africa

Region	Frequency of aflatoxin positive samples (%)	Contamination rate/concentration (AFM_1)	Remarks	References
Egypt	20	Mean 2.75 µg/kg		Alla *et al*., 2000
Egyptian	37	Detected		Polychronaki *et al.,* 2006
Egypt	36	10.27–21.43 pg/ml	Influence of socioeconomics	Polychronaki *et al.,* 2006
Egypt	56 July January	64 pg/ml (6.3–497 pg/ml) 8 pg/ml milk (4.2–108 pg/ml)	Seasonal pattern observed Influence of peanut consumption	Polychronaki *et al.,* 2007
Egypt	Milk powder (IFMP) Maternal breast milk (MBM)	74.413 ± 7.070 ng/l 9.796 ± 1.036 ng/l	Average daily exposure MBM = 52.684 ng/l IFMP = 8.170 ng/l	El-Tras *et al.,* 2011
Cameroon	4.8	0.005 – 0.652 µg/l		Tchana *et al.,* 2010
The Gambia	100			Hudson *et al.,* 1992
Nigeria	82	3.49–35 ng/l	Influence of socioeconomics	Adejumo *et al.,* 2013
Sierra Leone	91		Co-exposure	Jonsyn *et al.,* 1995
Sudan	54.2	Mean 0.401 ± 0.525 µg/kg Max. level of 2.561 µg/kg	Peanut butter, vegetable oils and rice influence AFM_1 burden	Elzupir *et al.,* 2012
Sudan and Zimbabwe		10–50 ppt (0.01–0.05 ng/l)		Wild *et al.,* 1987
Tanzania		0–0.55 ng/ml	AFM_1 Exposures 1.13–66.79 ng/k body wt/day	Magoha *et al.,* 2014

Deaths in humans, poultry, ducklings and dogs have been reported in many African countries due to aflatoxicosis outbreaks linked to the consumption of several contaminated products (Table 7).

Table 7: Reported aflatoxicosis outbreaks in Africa (1960–2016)

Year	Those affected	Numbers affected	Country	Sources of aflatoxins	Recorded effects with a focus on mortality	References
1960	Ducklings	16,000	Kenya - Rift Valley	Groundnut feed	Death	Peers and Linsell, 1973
1977/78	Dogs/ poultry	Large numbers	Kenya - Nairobi, Mombasa, Eldoret	Feed	Death	Muraguri, 1981; FAO, 1988
1981	Humans	12	Kenya - Machakos	Maize	Death	Ngindu *et al.,* 1982
1984/85	Poultry	Large numbers	Kenya	Imported maize	Death	CIMMYT *et al.,* 1986; FAO, 1988
1988	Human	3	Kenya - Meru North	Maize	Death	Autrup *et al.,* 1987
1989 1991	Poultry	Large numbers	Morocco	Feed (2,000–5,625 µg/kg)	Death	Kichou and Walser, 1993
2001	Humans	3 26	Kenya - Meru North Kenya - Maua	Maize	Death (16)	Probst *et al.,* 2007
2003	Humans	6	Kenya - Thika	Maize	Death	Onsongo, 2004
2004	Humans	317	Kenya - Eastern, Central	Maize	Death (125)	Lewis *et al.,* 2005
2005	Humans	75	Kenya - Machakos, Makueni, Kitui	Maize	Death (32)	Azziz-Baumgartner *et al.,* 2005; Daniel *et al.,* 2011
2006	Humans	20	Kenya - Makueni, Kitui, Machakos	Maize	Death (10)	Muture and Ogana, 2005; Daniel *et al.,* 2011
2007	Humans	4	Kenya - Kibwezi, Makueni	Maize	Death (2)	Wagacha and Muthomi, 2008
2008	Humans	5	Kenya - Kibwezi, Kajiado, Mutomo	Maize	Death (2)	Muthomi *et al.,* 2009
1967	Humans	3	Uganda	Cassava	Death (1)	Serck-Hanssen, 1970
1987, 2000, 2005	Dogs		South Africa - Gauteng Province	Dog food	Death	Bastianello *et al.,* 1987; Reyers and Miller, 2000; Naicker and Botha, 2005
2011	Dogs	Over 200	South Africa - Gauteng Province	Dog food (< 5–4,946 µg/kg)	Death	Arnot *et al.,* 2012

Year	Those affected	Numbers affected	Country	Sources of aflatoxins	Recorded effects with a focus on mortality	References
2016	Humans	67 9 (a family) Large number	Tanzania Dodoma, Manyara Chemba and Kondoa District, Dodoma	Cereals Cereals	14 confirmed deaths, 53 suspected cases	Buguzi, 2016

Source: Adopted from a Food and Agriculture Organization of the United Nations (FAO) report (Kangethe, 2011) and updated

2.2 Incidence of aflatoxin contamination of commodities (food and feed) by region

The data presented summarises the available literature on the occurrence of aflatoxins in a range of commodities (food and feed) across various regions in Africa as an indicator of the extent of the exposure. The data also reflects research efforts and various areas of interest across the continent. The data are not exhaustive.

Eastern Africa region

Among Eastern African countries, cereals (maize, rice, sorghum), peanuts, pulses, cassava and sweet potatoes are the major crops in terms of area planted and consumption. Overall, maize is the most worrisome followed by peanuts in terms of susceptibility and consumption of aflatoxin contaminated foods and feed (Table 8 and Table 9).

Kenya

Maize and other cereals such as millet and sorghum are staple foods depending on the region. Research on aflatoxins in Kenya has concentrated mostly on maize, peanuts and dairy farming. Maize-meal is consumed at a rate of about 258 g/person/day (ACDI/VOCAa, 2015) and has been the cause of all human aflatoxicosis outbreaks. Consumption of peanuts is at a lower level, estimated at 1.1 g/person/day. Both maize and peanuts also form major portions of the gruel used to wean children and these have been shown to be a source of aflatoxin exposure (Okoth and Ohingo, 2005; Nelson *et al.,* 2016). Most of the peanut samples tested are far beyond acceptable limits for aflatoxins as set by the Kenya Bureau of Standards (Table 8).

Regional variation in aflatoxin contamination of maize has been reported with drought-prone semi-arid eastern regions recording higher levels of contamination of up to 48,000 µg/kg (Daniel *et al.,* 2011; Kilonzo *et al.,* 2014) compared with the highlands and western Kenya that have recorded a high of 4,500µg/kg (Okoth and Kola, 2012; Mutiga, *et al.,* 2015). Sirma *et al.* (2015) reported levels of 0.17–5.3 µg/kg from 67% of maize collected from parts of the Rift Valley region, which is the major producer of maize in the country. Ninety-two percent of millet samples were positive for aflatoxins with a range of 0.14–6.4 µg/kg, while 50% of sorghum samples were positive with a range of 0.21–210.1 µg/kg. Home-grown maize has significantly lower levels of contamination than market samples, though those from eastern Kenya are still far above acceptable limits (Daniel *et al.,* 2011; Okoth and Kola, 2012; Mutiga *et al*., 2015). In 2010, surveillance of maize resulted in the confiscation of 2.3 million 90 kg bags of aflatoxin-

contaminated maize harvested in the country by Kenyan authorities (Njoroge, 2010). This harvest was considered unfit for both human and animal consumption.

Commercially processed products are also a source of exposure. In October 2011, 25 t of contaminated Unimix (a high-protein mix containing maize flour) destined for relief efforts in drought-affected areas of Kenya was recalled (Menya, 2011). Traditional maize preparation methods (e.g. fermentation and dehulling) in eastern Kenya have been reported to reduce aflatoxins by up to 71% (Mutungi *et al*., 2008).

Dairy farming is another source of aflatoxin exposure and high levels of AFB_1 have been recorded in feeds (Lanyasunya *et al.*, 2005; Kang'ethe and Lang'a, 2009) (see Table 8). Contaminated milk and milk products with aflatoxin AFM_1 is a concern. The list drawn up by Ochungo *et al.* (2016) of regions that are at risk of an aflatoxin outbreak from milk literally covers all production areas in the country. Protein-rich supplements (cottonseed cake, sunflower cake, fish-meal and other oil-seed by-products), cereal grains and their by-products (maize bran, maize germ, wheat bran and other grain milling by-products) are a rich source of nutrients for moulds. These fungi readily contaminate crop residues and homemade dairy concentrates as a result of poor handling and storage conditions in smallholder farms. This problem is worsened by farmers' widespread practice of using spoilt (pest- or mould-damaged) grains to formulate dairy rations.

Uganda

Plantains, cassava, maize, sweet potato and beans are – in that order – the most important staple foods in Uganda with consumption recorded at 172 kg, 101 kg, 31 kg, 82 kg and 16 kg/person/year, respectively (Haggblade and Dewina, 2010). Peanut consumption is lower, at 4.6 kg/year. Most research on aflatoxin contamination since the 1960s has focused on maize and peanuts. High incidence of liver cancer in the country has been attributed to consumption of aflatoxin-contaminated maize and peanut (Okobia and Bunker, 2003; Kaaya and Warren, 2005). Table 8 summarises comprehensive epidemiological studies conducted in Uganda on aflatoxin exposure from 1967 to 2001 (Kaaya and Warren, 2005). A greater proportion of these studies were conducted on foods sampled at the market-level than from farms, and they indicate that foods from the former are more contaminated with aflatoxins than from the latter, with some having levels above the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) Codex Alimentarius recommended limits of 20 µg/kg (FAO/WHO Codex Alimentarius, 2004). Not much has been reported on aflatoxin contamination of livestock feed, but it is believed that spoilt maize is used in animal feed.

Tanzania

Tanzania has the highest maize and peanut consumption rate (349 g/person/day and 15 g/person/day, respectively) among Eastern African countries (Lamb *et al.,* 2015). Other staples are cassava, rice, wheat and sorghum. According to 2012 prevalence data from Abt Associates, in collaboration with the Tanzania Food and Drugs Authority, aflatoxin contamination is a concern in the eastern (Morogoro) and western (Shinyanga) zones of Tanzania. In the eastern zone 43% of maize samples were above regulated levels (5 µg/kg), with an average contamination of 50µg/kg; and in the western zone, 40% of samples were above 5 µg/kg, with average contamination of 28µg/kg. In the southern zone (Ruvuma), none of the samples were above 5µg/kg. Groundnut samples from the northern, southern (Mtwara)

and western zones were contaminated with AFB_1 levels above 5 µg/kg; with mean contamination of 20 µg/kg, 18 µg/kg and 20 µg/kg respectively. Other data are captured in Table 8.

Burundi and Rwanda

Beans, maize, cassava, sweet potatoes and plantains are the major crops produced in these two countries. Maize consumption is 155 g/person/day in Burundi and 39 g/person/day in Rwanda (Lamb *et al*., 2015). Groundnut consumption is estimated to be much lower at 6.3 g/person/day in Burundi and 2.5 g/person/day in Rwanda. There is not much information on aflatoxin contamination of foods in Burundi and Rwanda, but levels as high as 425 µg/kg have been reported in groundnuts in Burundi (Constant *et al*., 1984). High contamination levels of all staple foods have also been reported with maize having up to 3,219 µg/kg, peanuts 1,755 µg/kg, cassava 534 µg/kg and beans 154 µg/kg (Nyinawabali, 2013). Aflatoxin exposure (ng/kg bwt/day) in Eastern African countries, based on data from Global Environment Monitoring System/Food data, are estimated at: Burundi 10–180; Kenya 3.5–133; Rwanda (no data); Tanzania 0.02–50; Uganda 10–180 ng/kg bwt/day (Palliyaguru and Wu, 2014).

Sudan

In Sudan, wheat, sorghum or maize flour is used to make porridge, which is a staple food. Beans and fish are also popular. Sudan is a leading global producer of peanuts; a key ingredient in Sudanese cooking and the most researched for aflatoxin contamination in that country. There is conformance to the high standards for the European export market. Sorting results in the elimination of contaminated kernels, however, rejected kernels find their way into the local market, particularly for oil-processing. Varying levels of aflatoxin contamination have been reported in the peanut value chains; 2%, 64%, 14% and 11 % for kernels, butter, cake and roasted peanuts, respectively (Younis and Malik, 2003). Other vegetable oils such as cottonseed, sesame and sunflower oil, are produced in local factories and consumed by almost all segments of the population. These oils, including peanut oil as well as other products, are a source of aflatoxin exposure (Table 8).

Low aflatoxin levels have been recorded in cereal grains and legume seeds collected from retailers (Abdel-Rahim *et al.*, 1989) but a 54% prevalence of aflatoxin contamination was found in commodities, feeds and feed ingredients sourced directly from livestock farms and feed production sites (Rodrigues *et al*., 2011).

Ethiopia

The major staple crops in Ethiopia include a variety of cereals (mainly teff, wheat and barley), pulses, oilseeds and coffee. Peanuts are one of the most valuable cash crops in eastern Ethiopia and are also consumed in large amounts. Aflatoxin contamination is endemic in Ethiopia due to predisposing factors such as end-season drought, harvesting methods and storage conditions, and low or limited knowledge of aflatoxins and related risks by value chains actors. Cereals, spices, pulses, peanut and dairy products are all high-risk commodities (Table 8 and Table 9). However peanut seems to be the most worrisome with high levels of aflatoxins reported in samples of peanuts from both storage facilities and markets (Eshetu, 2010; Chala *et al.*, 2013). Levels of AFB_1 as high as 738 µg/kg and 692 µg/kg have been found in peanuts and sorghum, respectively (Fufa and Urga, 2001). Use of less-susceptible varieties could reduce exposure as demonstrated by analyses of aflatoxin accumulation in different varieties

of peanut (Chala *et al.,* 2014a). Maize, millet, barley, red pepper and teff were most frequently found to have levels above 20 µg/kg. Exposure from consumption of staple cereals seems to be chronic, though at lower levels compared to exposure from peanut and its products (Chala *et al.,* 2014b; see Table 8).

Table 8: Frequency of aflatoxin contamination and concentration levels in household and market samples from Eastern Africa

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Ethiopia	Peanut		34.7	Bisrat and Gebre, 1981
	Peanut butter		105	
	Peanut		5–250	Amare *et al.,* 1995
Ethiopia	Peanut		**Storage samples**	Chala *et al.,* 2013
Babile		87	293–11,865	
Darolabu		88	15–4,939	
Gursum		59	15–5,563	
			Market samples	
Babile			15–9,765	
Darolabu			15–1,977	
Gursum			16–10,087	
Ethiopia	Spices	8	250–252	Fufa and Urga, 1996
	Legumes	13		
Ethiopia	Peanut	73	Trace: 447	Eshetu, 2010
Ethiopia	Barley, sorghum, teff and wheat		Trace: 26	Ayalew *et al.,* 2006
Ethiopia	Maize		< 26	Ayalew, 2010
Kenya - Eastern Province	Maize kernels	45	18–480 Mean dietary exposure: 292 ± 1,567 ng/kg bwt/day	Kilonzo *et al.,* 2014
	Dehulled maize (*Muthokoi)*	20	12–123 Mean dietary exposure: 27 ± 154 ng/kg bwt/day	

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
	Maize-meal	35	6–30 Mean dietary exposure: 59 ± 62 ng/kg bwt/day	
Kenya - Nairobi	Market samples for feed	95	> 10 (5.13–1,123)	Okoth and Kola, 2012
	Maize and maize products for food	83	> 10 (0.11–4,593.93)	
Kenya and Malawi	Malted grains	29	Non-detectable: 1,020	Kenji *et al.,* 2000
Kenya - Nairobi, Western Province	Peanut (82 fresh samples)	0–26.3	0–2377.1	Ndung'u *et al.,* 2013
Kenya - Eastern Province 2005 2006 2007	Maize 36 samples 18 samples 24 samples		Non-detectable: 48,000	Daniel *et al.,* 2011
Kenya - Western Province	Maize (14 samples from National Cereal Produce Board warehouses)	57 43 2 samples	> 20 ≥ 100 > 1,000	Lewis *et al.,* 2005
Kenya - Western Province	Maize (samples from households and markets) Maize for relief efforts	335.5 20.1 10.6	> 20 >100 > 1,000 < 20	Mwihia *et al.,* 2008
Kenya - Western, Nyanza and Nairobi Provinces	Peanuts and peanut products: Supermarkets Informal markets	 28 48	96% raw podded peanuts < 4 4% raw podded peanuts > 10 69% peanut butter and 75% spoilt peanuts > 10 68% of peanut samples stored in plastic jars >10	Mutegi *et al*b., 2013
Kenya	350 samples of maize and maize products from local markets and government warehouses	55 > 20 µg/kg 35 > 100 µg/kg 7 > 1,000 µg/kg	≤ 46,400 ≤ 1,800	CDC, 2004a,b; Lewis *et al*., 2005; Mutegi *et al*a., 2013

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Kenya - Western Province	Peanut		≤10	Mutegi *et al.,* 2012
Sudan	Sesame Groundnut	14.3 3.57	0.2–0.8 0.6	Idris *et al*., 2010
Sudan	Groundnut paste Peanut butter	16.67 97	12.93 < 10	Kabbashi and Ali, 2014
Sudan	Peanut butter (specialist health food outlets)	64 36 1 sample	< 10 16–318 345	Kabbashi and Ali, 2014
Sudan	Peanut, sesame, cottonseed oils from factories and traditional mills	14.3	43.7% sesame 0.2–0.8 3.57% groundnut 0.6	Yousif *et al.,* 2010
Sudan	Peanut butter and peanut samples		Average of 87.4 in west Sudan and 8.5 in central Sudan	Omer *et al.,* 1998
Sudan	Peanut butter	100	1–170	Elshafie *et al.,* 2011
Sudan	Peanut, sesame, sunflower and mixed oils from retailers and factories	36.8–100	0.43–339.9	Elzupir *et al.,* 2010
Sudan	Sorghum		11.13–120.2	Saeed, 2015
Tanzania	Maize	45–87	3–1,081	Kamala *et al.,* 2015
Tanzania	Maize	18	≤ 158 (12% > 10)	Kimanya *et al*., 2008
Tanzania	Maize-based foods	32	0.11–386 Mean dietary exposure: 1–786 ng/kg bwt/day	Kimanya, 2014
		44	57–825 Mean dietary exposure: 0.38–8.87 ng/kg bwt/day	
Uganda	Groundnut Groundnut paste	100 100	940 720	Osuret *et al.,* 2016

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Uganda	Maize, peanut and cassava	50	Positive	Kaaya and Miduuli, 1992
Uganda	Peanut (varieties) Kumi - newly harvested Kumi - stored 7 months Mayuge - newly harvested Mayuge - stored 5 months	 28 48 50 40	 0–5 0–22 0–10 0–18	Kaaya *et al.,* 2001
Uganda	Peanut (farm level)	60	7.3–12.4	Kaaya *et al.,* 2006
Uganda - southwest	Peanut, cassava, millet, sorghum flour, *eshabwe* sauce (90 food samples)		0–550	Kitya *et al.,* 2010
Uganda - mid-altitude (moist)	Maize kernels	83	9.7	Kaaya *et al.,* 2006
Uganda – mid-altitude (dry)		70	7.7	
Uganda - highland zone		55	3.9	
Uganda	Peanut		15% > 1 ppm 3% > 10 ppm	Lopez and Crawford, 1967
Uganda	Beans Maize Sorghum Groundnut Millet Cassava Rice (480 samples)	72 45 38 18 16 12	29%: 1–100 (all sample types except cassava) 8%: 100–1,000 (maize, beans, sorghum, peanut and cassava) 4% > 1,000 (beans, sorghum, peanut and cassava)	Alpert *et al.,* 1971
Uganda Produce Marketing Board and Animal Feed Mill	Maize, peanuts, soy beans, poultry feed	100	Trace - > 20	Sebunya and Yourtee, 1990
Uganda	Maize		0–50	Ssebukyu, 2002

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Uganda	Heinz mixed cereals, Cerelac, cornflakes		Non-detectable	Nakamya, 2008
	Wheetabix, porridge oats		10–20	
	Baby soya, *Kayebe, Mwebaza* rice porridge, jacinta millet and *Mukuza*		20–50	

Table 9: Aflatoxin contamination in feed and dairy products in Eastern Africa

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1	References
Kenya	Milk (processed)	100	0.012–0.127 µg/kg	Obade *et al.,* 2015
	Raw		0.0002–0.013 µg/kg	
Kenya	Dairy products	59	< 2 ppt	Sirma *et al*., 2014
		32	2–50 ppt	
		9	> 50 ppt	
Kenya	Animal feed (830 samples)	86	67% > 5 µg/kg	Kang'ethe and Lang'a, 2009
	Milk samples (613 samples)	72	20% > 0.05 µg/l	
Kenya	Milk samples	45.5	49% > 0.05 µg/l	Kang'ethe *et al.,* 2007
	Animal feed	98.6	83% > 10 µg/kg	
Sudan	Groundnut cakes (18 samples)	11	0.013 µg/kg	Walaa *et al.*, 2015
			0.014 µg/kg	
Sudan	Cow milk (35 samples)		100% > 0.05 µg/kg	Ali *et al.,* 2014
			77% > 0.5 µg/kg	
	Powdered milk (12 samples)		50% > 0.05 µg/kg	
			33% > 0.5 µg/kg	
Sudan	Cattle milk	95	0.22–9.60 µg/l	Elzupir and Elhussein, 2010

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1	References
Ethiopia	Animal feed	All samples	0.028–4.98 µg/kg	Gizachew *et al.,* 2015
	Milk (dairy farmers)	8.2	≤0.05 µg/kg	
	Milk (traders)	26.3	>0.5 µg/kg	
	Feed (dairy farmers)	All samples 10.2	7–419 µg/kg ≤ 10 µg/kg	
	Feed (feed producers, processors and traders)	26.2	> 100 µg/kg	
	Wheat bran		31 µg/kg	
	Noug cake		290–397 µg/kg	

EU limit of AFM_1 in milk = 0.05 µg/kg

Codex Alimentarius (Codex) limit of AFM_1 in milk = 0.5 µg/kg

WHO/FAO (Codex) limit of AFM_1 is 0.05 µg/kg

West Africa region

Staple foods in West Africa are maize, cassava, yam, rice and plantains, served with beans, legumes, meats, fish, peanut sauce, palm oil, spices and chillies. Countries include Benin, Burkina Faso, Cameroon, Cape Verde, Côte d'Ivoire, Equatorial Guinea, Gabon, The Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Nigeria, Senegal, Sierra Leone and Togo. Generally there is a wide variation in climate conditions ranging from tropical hot and humid conditions in most of West Africa to desert and arid conditions in the northern parts of Mali and Niger. The varying temperatures and humidity are favourable for the growth of toxigenic fungi and mycotoxin production. Tables 10, 11 and 12 provide an overview of aflatoxin contamination in West Africa as well as data on the export notifications from West Africa to Europe based on literature reviewed. Aflatoxin contamination has significantly constrained exports of peanut from West Africa to European markets.

Nigeria

Numerous surveys on aflatoxin contamination of food and feed in Nigeria have been carried out (Table 10) which indicate a wide range of commodities are impacted. Recorded aflatoxin readings are as high as 1,000–5,000 µg/kg in groundnut, maize, rice and millet beer. The Nigeria Mycotoxin Awareness and Study Network has created mycotoxin maps of the country that summarise the occurrence of aflatoxin contamination in maize and peanuts (Figure 3 and 4) respectively. The Southern Guinea Savanna and Sudan Savanna zones in Nigeria have been reported to have significantly higher aflatoxin contamination than other cooler dryer agro-ecological zones (Udoh *et al.,* 2000).

Table 10: Aflatoxin contamination in household and market samples from Nigeria

Commodities contaminated	Frequency of contamination	Range of concentration (µg/kg)	Mean concentration (µg/kg or µg/l)	References
Groundnut		100–2,000		Darling, 1963
Maize	100%	30.9–507.9		Atehnkeng *et al.,* 2008
Stored maize grains		137.33–596.85		Adetuniji *et al.,* 2014
Stored groundnut	35%	100–2,000		Peers, 1965
Palm wine				Bassir and Adekunle, 1969
Bitterleaf		> 94		Bassir, 1969
Groundnut Dried fish Cereals (millet sorghum and rice)		> 900 600–700 150–300		Okonkwo and Nwokolo, 1978
Sorghum		< 20		Dada, 1978
Sorghum	8/8 8/8	30.32–211.2 2.4–208		Uriah and Ogbadu, 1982
Groundnut Groundnut oil Cottonseed oil		0–600 > 98 > 65		Abalaka and Elegbede, 1982
Poultry feed made of groundnut cake (aflatoxicosis in pekin ducklings)			3,000	Ikwuegbu, 1984
Livestock rations		4–340		Gbodi *et al.,* 1984
Poultry feed	69/120	0.57–2.55		Oyejide *et al.,* 1987
Maize	27/64 21/64 5/6 43/64	0–960 0–543 0–83.33 0–23.53	0.27–372.49 1.5–113.2 2–203 92–13.33	Gbodi, 1986
Acha	4/24 2/24	0–20 0–12		
Cottonseed	3/8 3/8 2/8 1/8	0–271 0–36.6 0–183 0–9.1	52.25 24.85 38.13 1.14	

Commodities contaminated	Frequency of contamination	Range of concentration (µg/kg)	Mean concentration (µg/kg or µg/l)	References
Millet beer	10/10	500–5,000		Obasi *et al*., 1987
Peanut cake	18/20 29/29	20–455 13–2,824	236.69	Akano and Atanda, 1990; Ezekiel *et al*., 2012
Cowpea Maize Millet Rice Sorghum Cottonseed Groundnut Groundnut oil Melon seed Palm kernel	3/268 81/281 10/275 13/279 22/318 17/28 414/634 56/57 22/30 41/55	0–48 0–1,250 0–160 0–40 0–40 0–8,000 0–40 0–53	31.6 74–218 42 5 5 105 151–767 9.5 19	Opadokun, 1992 (samples collected from 1962–1985)
Restaurant dishes (*gari*, bean with soup) Dried okra Dried pepper	17/17	31.2–268.32		Obidoa and Gugnani, 1990
Maize Maize cake Maizeroll snack		25–777 15–1070 10–160	200 233 55	Adebajo *et al*., 1994
Red hot chili pepper		> 2.2		Adegoke *et al*., 1996
Maize	144/288	234–908 234		Tijani, 2005
Human milk Cow milk Ice cream	5/28 3/22 2/6		4 3.02 2.23	Atanda *et al.,* 2007
Mouldy rice	97/196	0–1,642	200.19	Makun *et al.,* 2007
Mouldy sorghum	91/168	0–1,164	199.51	Makun *et al.,* 2009a Makun *et al.,* 2009b
Powdered milk Bean Wheat	7/100 29/50 27/50	0–0.41 0–137.6 0–198.4	0.016–0.325 59.29 85.56	Makun *et al*., 2010

Commodities contaminated	Frequency of contamination	Range of concentration (µg/kg)	Mean concentration (µg/kg or µg/l)	References
Rice	21/21 21/21 21/21 19/21 21/21	4.1–309 1.3–24.2 5.5–76.8 3.6–44.4 27.7–371.9	37.2 8.3 22.1 14.7 82.5	Makun *et al.,* 2011
Melon seed	30/120	2.3–15.4		Bankole and Mabekoje, 2004
Maize	20/103	3–138		
Fonio millet	13/16 4/16 4/16	0.08–1.4 0.07–0.1 0.2–2	0.4 0.08 0.6	Ezekiel *et al.,* 2012
Commercial poultry feed	44/58 29/58 35/58 6/58	6–1,067 10–114 8–235 10–20	198 34 45 13	Ezekiel *et al.,* 2012
Rice Beans Cassava flour Semovita Yam Wheat meal Maize *Gari* Human milk	19/21 15/17 3/4 2/6 6/7 2/3 3/3 13/18 41/50	*nd –0.3 nd–0.89 nd–0.07 nd–0.17 nd–0.27 nd–0.06 0.11–0.2 nd–0.69 nd–92.14(ng/l)	0.14 0.15 0.05 0.09 0.14 0.04 0.16 0.25 15 (ng/l)	Adejumo *et al.,* 2013
Dried yam chips	97.5%	190		Abiala *et al.,* 2011
Rice samples	18.4%	Mean of 5		Abdus-Salaam *et al*., 2015
Maize Maize cake Maize roll snacks	45% 80% 12%	25–770 15–1,070 10–160		Adebajo *et al.,* 1994
Pre-harvested maize	18.4%	3–138		Bankole and Mabekoje, 2004
Maize Maize-based gruels	45% 25%	25–770 0.002–19.716		Williams *et al*., 2004
Maize	2–19%	716 4.6–530		Oyelami *et al.,* 1996

Commodities contaminated	Frequency of contamination	Range of concentration (µg/kg)	Mean concentration (µg/kg or µg/l)	References
Muscle tissue/beef		Fresh samples 21.7 Sundried samples 2.9		Oyero and Oyefulo, 2010
Liver		Fresh samples 33.9 Sundried samples 3.1		
Heart		Fresh samples 55.9 Sundried samples 27.9		
Kidney		Fresh samples 85.2 Sundried samples 75.8		
Pepper	12/20	0.05–19.45	0.39–2.21	Makun *et al.,* 2012
Milk types	100%	0.15–0.96		Okeke *et al.,* 2012
Poultry feed	100%	0–67.9	15.5	Adebayo-Thato and Etta, 2010
Peanut cake		20–455		Akano and Atanda, 1990
Peanut cake	90%	> 20		Ezekiel *et al*., 2012
Rice	64/86 41/86	4–292 0.4–27.2	157.34 5.17	Olorunmowaju, 2012
Groundnut	72/82 61/82	4–188 0.4–38.4	53.06 8.08	Ifeji, 2012

* Not detectable

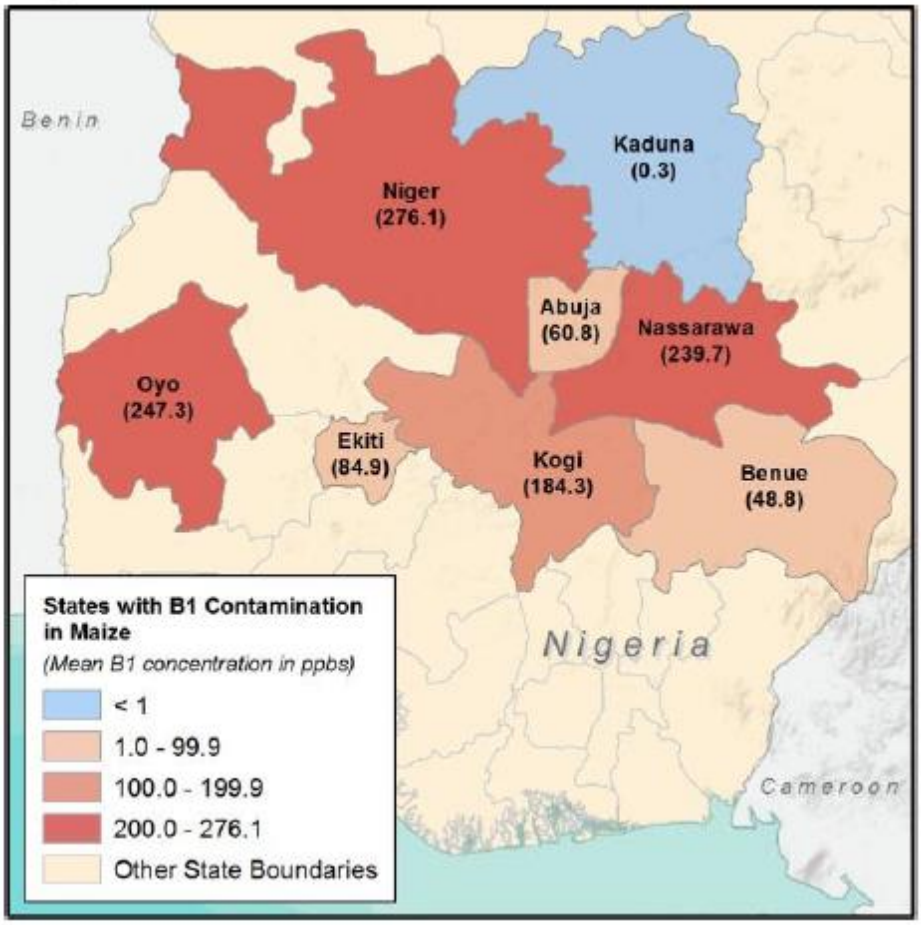

Figure 3: Aflatoxin B_1 contamination in maize in Nigeria

Source: Adapted from: Abt Associates, 2012a

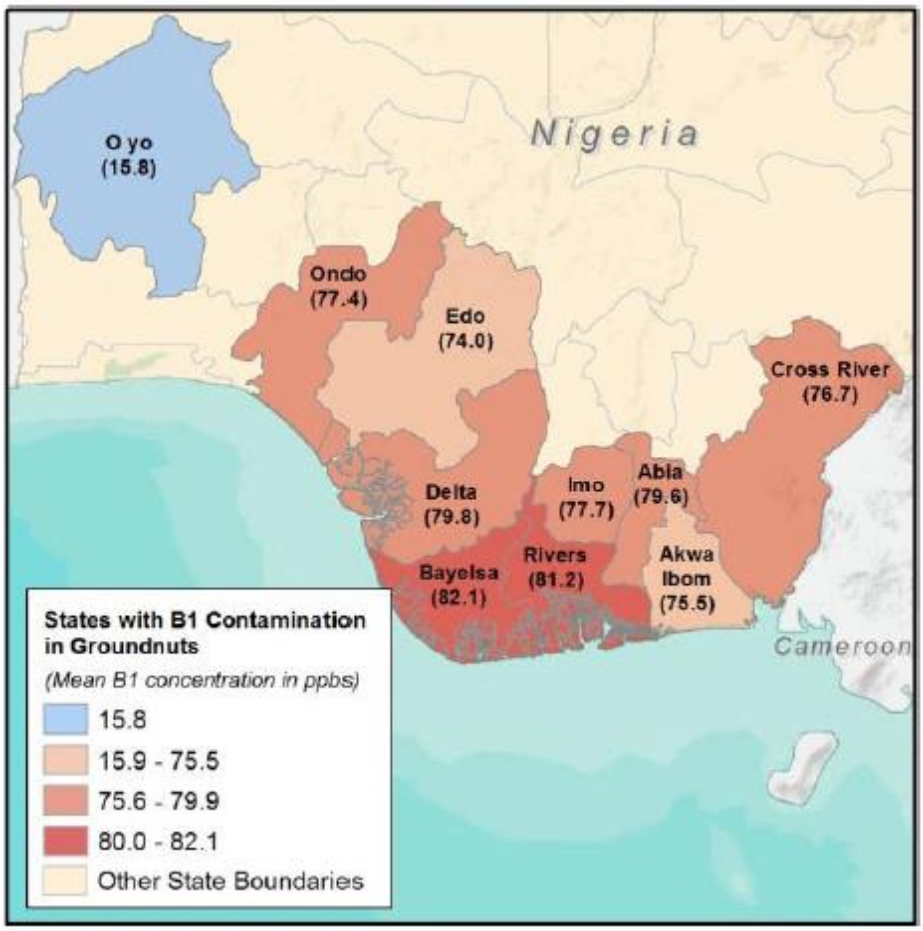

Figure 4: Aflatoxin B_1 contamination in groundnuts in Nigeria

Source: Adapted from: Abt Associates, 2012a

Benin and Togo

In Benin and Togo, maize is a staple food, consumed and stored across all agro-ecological zones and a major source of aflatoxin contamination. There have been reports of higher aflatoxin accumulation from the south to the northern drier parts in Benin (Setamou *et al.,* 1997) and in other commodities (e.g. dried yam, okra and pepper) (Table 11).

Traditional processing of maize for the preparation of maize-based foods (*makume*, *akassa*, and *owo*) in Benin was shown to reduce aflatoxin content by up to 93% (Fandohan *et al.,* 2005). Effective methods for significant aflatoxin removal were sorting, winnowing, washing and crushing combined with dehulling of maize grains (Fandohan *et al.,* 2006). Fermentation and cooking showed little effect (Fandohan *et al.,* 2005).

Ghana

Peanuts and maize are the crops most researched when looking at aflatoxins in Ghana. Peanut samples from the 1994 crop season in six locations in southern Ghana contained aflatoxin concentrations at levels ranging from 12–110 µg/kg (Awuah and Kpodo, 1996). A higher range of contamination (5.7–22,000 µg/kg) was obtained from damaged kernels sampled during a nationwide survey covering 12 markets in all 10 regions of Ghana, demonstrating the importance of sorting as a useful method of aflatoxin management.

Aflatoxins were not detected in 50% of visibly undamaged kernels tested and were present at low levels (0.1–12 µg/k) in the remaining undamaged kernels (Awuah and Kpodo, 1996). High levels of aflatoxins were recorded in maize collected from silos and warehouses and fermented maize dough samples from major processing sites and markets (Kpodo *et al*., 1996; Kpodo, 2001; see Table 10). In a separate study, implementation of good manufacturing practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) in traditional processing of *kenkey* in a plant in Accra was shown to reduce aflatoxins. Levels of aflatoxins in *kenkey* samples reported at the plant before implementation of GMP and HACCP were between 64.1 and 196 µg/k, and after implementation dropped to between 14.5 and 17.2 µg/k (Amoa-Awua *et al.*, 2007).

Other West African countries (Senegal, the Gambia and Guinea Bissau)

Peanut is the principal export crop constituting 80% and 66% of the earnings from agricultural exports in Senegal and The Gambia, respectively. Its production, handling, processing and marketing employ 86% and 70% of the active labour force in Senegal and Gambia, respectively. The UK imports most of Senegal's peanut exports (86%) (Caswell, 1985). In The Gambia, on average, 45% of agricultural land is annually allocated to peanut, with production fluctuating around 107,000 t. Guinea Bissau does not export peanuts. Being a staple food, consumption of contaminated peanut results in chronic aflatoxin exposure, as confirmed by high levels in cooked food in The Gambia (Hudson *et al.,* 1992; Turner *et al.,* 2000; Wild and Hall, 2000).

Table 11: Aflatoxin contamination in household and market samples from Nigeria

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Benin	Dried yam	98	2.2–220 (mean 14)	Bassa *et al.,* 2001
Benin	Cereals		≤ 14 ≤ 58 AFG_1	Bouraima *et al.,* 1993
Benin	Cashew nuts		Not detectable	Lamboni *et al.,* 2016
Benin	Yam chips	20 80	> 15 > 4	Mestres *et al*., 2004
Benin (four agro-ecological zones)	Cowpea		Not detectable	Houssou *et al.,* 2009
Benin	Cassava chips		Not detectable	Gnonlonfin *et al.,* 2012
Benin - North zone Benin - South zone	Maize	56 25	2–2,500 (mean 220) (mean 100)	Hell *et al*., 2000a; Hell *et al*., 2000b

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Benin, Mali and Togo	Dried okra Dried hot pepper		Mean 6 Mean 3.2	Hell *et al*., 2009
Benin and Togo	Maize, peanut	91	3.6% > 20	Egal *et al.,* 2005
Burkina Faso	Maize Groundnuts Animal feed	50 50 22		Kpodo *et al.,* 2000; Warth *et al.,* 2012
Burkina Faso, Niger, Senegal	Peanut		1–450 (mean 143)	Waliyar *et al*., 1994
Côte d'Ivoire	Oilseeds		<20	Kershaw, 1982
Côte d'Ivoire	Peanut	13	>50	Wyers *et al.,* 1991; Kouadio *et al.,* 2014
Côte d'Ivoire	Maize	12.6 7.9 4.4 73	≤ 360 > 250 > 1,000 > 10	Pollet *et al.,* 1989
Côte d'Ivoire	Cereals	86	> 20	Sangare-Tigori *et al.,* 2006
The Gambia	Groundnut sauce	90	19–944 (mean 162)	Hudson *et al.,* 1992
	Maize	90	2–35 (mean 9.7)	
	Millet	100	1–27 (mean 9.8)	
	Sorghum	25	2–16	
	Rice	70	2–19 (mean 7.9)	
	Leaf sauces	100	21–34	
Ghana	Peanut	31.7	12.8	Williams *et al.,* 2004
Ghana	Weaning food	100	7.9- 500	Kumi *et al*., 2015
Ghana	Peanut		3–220	Mintah and Hunter, 1978
Ghana	Maize		355 2–662	Kpodo *et al*., 1996; Kpodo *et al.*, 2000
Ghana (silos and warehouses)	Maize		20–355	Kpodo *et al*., 1996
Ghana (processing sites)	Fermented maize dough		0.7–313	

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Ghana	*Kenkey* Maize kernel	77 66	≤ 200 ≤ 2,000	Kpodo, 2001
Ghana	Weanimix (weaning food from beans, groundnut and maize)	100	7.9–500	Kumi *et al.,* 2014
Ghana	Peanut paste (100 samples)	86	65 samples > 30 (highest = 3,300)	Kpodo, 1997
Ghana	Sorghum	3	7.5 8 8.1	Bankole and Kpodo, 2005
	Soya beans	5	≤ 36	
	Cassava	4	4–21	
	Cashew paste	3	≤ 370	
	Rice		< 2	
	Maize cake		< 8	
	Agushie		< 15	
Mali	Peanut		47–2,100	Soler *et al.,* 2010
Mali	Peanut butter		2.34–189.34	Babana *et al.,* 2013
Mali	Peanut		≤ 20	Waliyar *et al.,* 2015
Niger (1989, 1900 and 1991)	Peanuts (26 lines)	37	1–750	Waliyar and Hassan, 1993
Senegal	Peanut oil	80	57–82 (mean 40)	Diop *et al*., 2000
Senegal	Peanut butter	90	2.3–189.3	Keita *et al*., 2013
Senegal	Maize Sesame		120 1.2	Diedhiou *et al.,* 2011
Senegal	Peanut oil	85	40 4.6–530	Williams *et al.,* 2004
Sierra Leone	Fish, fermented food			Jonsyn 1989; Jonsyn and Lahai, 1992

Table 12: Export notification of peanut from West African countries to Europe

Notified by	Countries concerned	Subject
France	France (D), Togo (O)	Aflatoxins (B_1 = 128.1; total = 133.2 µg/kg) in raw peanuts in shell from Togo
Lithuania	The Gambia (O), Lithuania	Aflatoxins (B_1 = 101; total = 144 / B_1 = 30; total = 46 µg/kg) in groundnut kernels from The Gambia
Poland	Poland, Senegal (O)	Aflatoxins (B_1 = 80.56; total = 95.57 / B_1 = 76.77; total = 90.94 µg/kg) in raw groundnut kernels from Senegal
UK	Poland, Senegal (O)	Aflatoxins (B_1 = 39.57; total = 43.77 / B_1 = 30.14; total = 33.44 µg/kg) in groundnut kernels from Senegal
UK	Nigeria (O), Spain, UK	Aflatoxins (B_1 = 65; total = 84 µg/kg) in groundnut oil from Nigeria
UK	Nigeria (O), Spain, UK	Aflatoxins (B_1 = 19; total = 23 µg/kg) in peanuts from Nigeria
UK	Ghana (O), Spain, UK	Aflatoxins (B_1 = 100; total = 120 / B_1 = 28; total = 30 µg/kg) in groundnut paste (peanut butter) and groundnuts
UK	Ghana (O), Spain, UK	Aflatoxins (B_1 = 76; total = 112.7 µg/kg) in peanut butter from Ghana

O = origin; D = destroyed

European Commission (EC), Rapid Alert System for Food and Feed (RASFF) Portal: https://webgate.ec.europa.eu/rasff-window/portal

Source: Adapted from Senghor (2015)

Central Africa region

Central Africa consists of Cameroon, Central African Republic, Chad, Republic of the Congo and the Democratic Republic of Congo (DRC). The staple foods of this region are cassava, rice, millet, sorghum, squash, pumpkin and plantain. There is little information on aflatoxin contamination in this region except for Cameroon (Table 13). High levels of aflatoxins were reported in peanuts collected from rural areas in Kinshasa in DRC (Kamika and Takoy, 2011). AFB_1 levels increased from the dry season to the rainy season with values ranging from 1.5 to 390 and 12 to 937 µg/kg, respectively. Seventy percent of the peanut samples from both seasons exceeded the maximum limit of 5 µg/kg. In a separate study, 75% of peanut samples exceeded the maximum limit (Ilunga, 2014).

Table 13: Aflatoxin contamination in household and market samles from Cameroon

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/total concentration of AFB_1 (µg/kg)	References
Cameroon	Maize Peanut meal Poultry feed mixtures	9 100 93.3 (broiler) 83 (layer feed)	≤ 2–42 39–50 2–52 2–23	Kana *et al.,* 2013
Cameroon	Eggs		7.86	Speijers and Speijers, 2004
Cameroon	Cassava chips	33	5.2–14.5	Essono *et al.*, 2008
Cameroon	Dried food commodities	51	Mean 2.6	Njobeh *et al.,* 2010
Cameroon	Maize Peanut Cassava	74 62 24	6–645 6–125 6–194	Ediage *et al*., 2014

North Africa region

Algeria, Egypt, Libya, Mauritania, Morocco, Sudan and Tunisia make up North Africa. Their major staples are wheat, barley, rice, nuts, herbs, beans and pulses. Spices are also used extensively to flavour food and as medicines.

Egypt, Libya and Morocco

The preservative and antioxidant properties of spices make them highly valuable. Spices are reported to be a significant source of aflatoxin exposure due to the tropical climatic conditions in areas where they are grown. Furthermore they are usually dried on the ground in the open air in poor hygienic conditions that promote growth of moulds and production of mycotoxins (Martins *et al.,* 2001). In Cairo, aflatoxins were detected in processed meat that contained spices but aflatoxins were absent in fresh meat (beefsteak and minced meat), canned meat, salami. The contamination of processed meat with aflatoxin was shown to be correlated with the addition of spices to fresh meat (Nagy and Youssef, 1991). Aflatoxins ranged from 8–35 µg/kg in spices and 2–150 µg/kg in processed meat. When 120 samples of 24 different spices were examined in Egypt, an aflatoxin range of 8–35 µg/kg was recorded in 16 samples of anise, black pepper, caraway, black cumin, fennel, peppermint, coriander and marjoram (El-Kady *et al*., 1995). Similar levels have been reported in Morocco. Peanuts and dairy products are also of concern in this region (Table 14).

Table 14: Frequency of aflatoxin contamination and concentration levels in household and market samples from North Africa

Country	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/concentration (µg/kg)	References
Egypt	Hazelnut	90	25–175	Abdel-Hafez and Saber, 1993; Williams *et al.,* 2004
	Peanut and watermelon seeds	82	Positive	
	Soybean	35	5–35	
	Spices	40	> 250	
	Walnut	75	15–25	
Egypt	Milk	38	0.023–0.073	Amer and Ibrahim, 2010
Egypt	Raisin	3	220–300	Youssef *et al.,* 2000
Egypt	Peanut		1,056 (AFM_1)	El-Gohary, 1996
Egypt	Milk Cheese	20 10–20	3–6 (AFM_1) 0–0.5 (AFM_1)	Alla *et al*., 2000
Egypt	Cereal, pulses, fenugreek, peanut, and cottonseed cake	33	3–12	Girgis *et al.*, 1977
Egypt	Maize Rice		9.75 5.15	Madbouly *et al.,* 2012
Libya	Milk Cheese	71 17	0.03–3.13 ng/ml (AFM_1) 0.11–0.52 ng/ml (AFM_1)	Elgerbi *et al*., 2004
Libya	Maize	9	7.1–13.9	Youssef, 2009
Libya	Commercial baby cereals	2.4	19–70	Kofi *et al.,* 2011
Morocco	Milk	88.8	0.001–0.117 µg/l (mean 0.0186 µg/l) 3.26 ng/person/day	Zinedine *et al.,* 2007b
Morocco	Poultry feed	4 17 1 farm	≤ 110 110–200 2,000–5,625	Kichou and Walser, 1993
Tunisia	Sorghum	38	15.4	Oueslati *et al.,* 2014

Southern Africa region

Maize, groundnuts and cassava are major food and cash crops in Southern Africa and are the crops most researched regarding aflatoxins. Samples of a range of commodities from selected

countries (Botswana, Malawi, Zambia and Zimbabwe) have been found to contain unacceptable levels of aflatoxins (Table 15). Levels of contamination and exposure in the Republic of South Africa based on literature reviewed are profiled in Table 16.

Botswana, Malawi and Zambia

In Botswana, Mphande *et al.* (2004, 2014) reported the presence of aflatoxins greater than 20 µg/kg in half of the samples of peanut meals. In Malawi levels of up to 1,020 µg/kg were reported in grains (Glaston *et al.*, 2000). In a separate study AFB_1 was detected in 45.3% of the maize samples with 12.3% of them exceeding 5 µg/kg. The traditional flour production procedures reduced AFB_1 significantly in this order: soaking of dehulled maize (72.4±5.4, 75.4±3.5 and 80.9±5.3% for 24, 48 and 72 h soaking periods, respectively) > dehulling of maize (mean 29.3±5.4%) > sun drying (11.7% max). Sun drying followed pseudo-first order kinetics in AFB_1. A maximum AFB_1 reduction of 88.1 ± 3.1% was achieved using a sequence of dehulling, soaking for 72 h and sun drying the flour for 4.5 h (Matumba *et al*., 2009). Njapau *et al.* (1998 also observed that village processing techniques in Zambia reduced aflatoxin content of maize and peanut products. In 30 trials, maize kernels were dehulled, soaked for 24 h, washed and dried before grinding into flour and boiling in water to a thick consistency (*Nshima*). Shelled peanuts were either dry-roasted as whole kernels or ground into peanut meal and cooked. Dehulling, following by 24 h soaking (steeping) and subsequent washing significantly reduced the aflatoxin B_1 content of maize flour from 900 to 150 µg/kg, and similarly that of aflatoxin G_1 from 929 to 114 µg/kg. Preparation of *Nshima* did not result in a substantial reduction in aflatoxin content, and neither did extension of the cooking duration of 2 h. Whereas boiling peanut meal yielded a moderate reduction in the content of aflatoxins B_1 and G_1, roasting whole peanut kernels greatly reduced (P<0·001) the concentrations of the toxins from that in raw kernels (AFB_1 = 8600 µg/kg and AFG_1 = 6200 µg/kg) to 1300 and 1200 µg/kg, respectively.

All malt and beer samples in Malawi, and 15% and 43% of the sorghum and *thobwa* (opaque sweet beverage) samples, respectively, collected from the southern region of Malawi during the humid month of January 2010, were contaminated with aflatoxins. The sorghum malt prepared for beer brewing had a significantly higher total aflatoxin content (average 408 ± 68 µg/kg Standard Error of the Mean [SEM]) than any other type of sample. The average aflatoxin content in the beer was 22.32 µg/l, which is higher than the permissible maximum level in ready to eat foods set by the Codex Alimentarius Commission (10 µg/kg). Thus consumption of opaque sorghum-based traditional beer poses a risk of aflatoxin exposure.

In a separate study, traditional maize based opaque beers collected from tribal (*chewa*) rituals and commercial village brewers from Lilongwe and Dowa districts in Malawi in August 2012 were analysed for aflatoxins. With exception of one beer sample, all the beers contained aflatoxins at a mean concentration of 90 ± 95 µg/kg. Consumption of 1.0–6.0 l of the traditional beer from this study translates to daily aflatoxin exposure of 1.5–9.0 µg/kg bwt/day for a 60 kg adult (Matumba *et al*., 2014).

Cassava is the second most important staple (after maize), nourishing over 30% of the population in Malawi and Zambia. As cassava is highly perishable, it is often processed into dry forms such as *kadonoska, kanyakaska, makaka,* and fermented and unfermented flour to increase shelf life. *Kadonoska, kanyakaska* and *makaka* are processed into flour for *nsima* (in Malawi) or *nshima* (in Zambia), confectioneries or stored for later use. A study was conducted

to assess the level of fungal and mycotoxins' contamination in commonly processed cassava products. A total of 92 and 88 samples of processed cassava products comprising *makaka*, flour, *kanyakaska*, *kadonoska*, scrapes and grates were collected in the rainy season of 2008 and 2009 in Malawi, respectively. Further, 22 samples of processed cassava products comprising dried cassava chips and flour were collected in the rainy season of 2009 in Zambia. None of the samples in 2008 were contaminated with aflatoxins. Similar results were obtained in 2009, with almost all the samples in Malawi and Zambia having aflatoxin levels much lower (<2.0 µg/kg in Malawi and <4.2 µg/kg in Zambia) than the Codex Alimentarius Commission maximum permissible level of aflatoxins of 10.0 µg/kg, implying that the cassava products analysed were safe for human consumption (Chiona *et al*., 2014).

Peanut is also an important crop in Malawi both as food and a cash crop. A total of 1,397 groundnut samples collected from farm homesteads, local markets, warehouses and shops in 2008 and 2009 had 46% and 23% of the total samples respectively contaminated with levels greater than 4 ppb, and 21% of the samples in 2008 and 8% in 2009 were above 20 ppb. Similarly high AFB_1 contamination, was recorded across the country with 11–28% of all samples collected from the warm low to mid-altitude ecologies, recording contamination ≥20 ppb and low contamination (2–10% of samples) in the mid to high altitude cool ecologies (Monyo *et al.*, 2012). In a recent study, samples of locally (Malawian) processed and imported maize- and groundnut-based food products (peanut butter, roasted groundnuts, peanut based therapeutic foods, instant baby cereals, maize puffs and de-hulled maize flour) were collected from popular markets in Lilongwe and analysed for aflatoxins. No aflatoxins were detected in all samples of imported baby cereal and locally processed de-hulled maize flour. However, all locally processed maize-based baby foods had aflatoxins above the EU maximum tolerable level of 0.1 µg/kg set for food for health purposes. In 75% of locally processed maize puffs, aflatoxins were detected at levels of up to 2 µg/kg. Peanut based therapeutic foods had aflatoxin level between 1.6 and 2.9 µg/kg. Locally processed peanut butter had aflatoxin levels in the range of 34.2–115.6 µg/kg, which was significantly higher than their imported counterparts (<0.2–4.3 µg/kg). Samples of locally processed skinned and de-skinned roasted groundnuts contained aflatoxin levels in the range of 0.5–2.5 µg/kg and 0.6–36.9 µg/kg, respectively. These results show that publicly marketed foods are a source of exposure (Matumba *et al.*, 2014).

Table 15: Frequency of aflatoxin contamination and concentration levels in household and market samples from Southern Africa

Region	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/concentration (µg/kg)	References
Botswana	Peanut	78	12–329	Mphande *et al.,* 2004
Botswana	Sorghum Peanut Maize	40 71 0	1–64 (mean 0.3) 1.64 (mean 23)	Siame *et al.,* 1998
Botswana	Opaque beer	0		Nkwe *et al.,* 2002
Botswana	Peanut butter	0	0	Mupunga, 2013
Malawi	Grains	12.3	1,020 > 5	Glaston *et al.,* 2000
Malawi	Opaque beer	99	90 ± 95	Matumba *et al*., 2014
Malawi	Sorghum malt for *thobwa* Sorghum malt for beer Beer *Thobwa*	100 100 100 43	6.1–54.6 µg/l 4.3–1138.8 µg/l 2.1–7.1 µg/l 8.8–34.5µg/l	Matumba *et al.,* 2011
Malawi	Peanut 2008 2009		46% > 4 23% > 4	Monyo *et al.,* 2012
Malawi	Maize	100	2–150	Mwalwayo and Thole, 2016
Malawi	Imported baby cereal and locally processed (LP) de-hulled maize flour	100	Not detectable	Matumba *et al.,* 2014
	LP maize-based baby foods	100	> 0.1	
	LP peanut-based foods	75	1.6–2.9 34.2–115.6	
	LP peanut butter		< 0.2–4.3	
	Imported peanut butter		0.5–2.5	
Malawi and Zambia	Cassava flour (2008 and 2009)		Malawi < 2 Zambia < 4.2	Chiona *et al*., 2014

Region	Commodity	Frequency of aflatoxin-positive samples (%)	Contamination rate/concentration (µg/kg)	References
Zambia	Peanuts	55	0.014–48.67	Bumbangi *et al.*, 2016
Zimbabwe	Peanut Peanut butter	 100	6.6–622 6.8–250 (mean 73.5)	Mupunga, 2013

South Africa

South Africa has both a well-developed commercial farming system and subsistence farming. Maize and groundnuts are the crops of interest for aflatoxins, especially in rural areas. Individual samples of agricultural commodities specifically submitted over a 10-year period (1984–1993) to a commercial testing service found aflatoxin contamination in 229 of the 1,602 submitted samples, with levels in maize, other cereals, oilseeds, poultry feed, animal feed, forage and soybean in the range of 1–500 µg/kg (Dutton and Kinsey, 1996). Surveys carried out by the South Africa Maize Board (SAMB) since 1986 shows low incidence of aflatoxin contamination in local maize. Analytical reports from SAMB showed that contamination of unprocessed commercial maize was nil or < 2µg/kg in the following years: 1986 (n=456), 1987 (n=496), 1988 (n=277), 1990 (n=55) and 1991 (n=166) (Viljoen *et al*., 1993; Rheeder *et al*., 1995). From 1992 onwards, higher levels have been reported as shown in Table 16. Surveys on maize and groundnuts produced by subsistence farmers during the 2005/06 and 2006/07 seasons in KwaZulu-Natal, recorded an increased area with contamination of up to 20 µg/kg compared to the 2004/05 season. Incidences of > 20 µg/kg were also reported. Surveys of commercial sorghum during the 2007/08, 2008/09 and 2009/10 seasons recorded mean contamination of up to 0.9 µg/kg (Flett *et al.,* 2015). Aflatoxin contamination in peanut butter used in a national school-feeding programme showed contamination of 271 µg/kg (PROMEC Unit, 2001). Generally, overall contamination levels are low, but high levels are sporadically observed. Regular monitoring of commodities is paramount.

Contamination of feed and animal products is also of interest in South Africa due to previous aflatoxicosis outbreaks in animals following consumption of contaminated feed. Analysis of samples of feeds, forage, maize and milk taken at nine dairy farms, and processed milk collected from the dairies to which the farms had delivered their fresh milk showed aflatoxin contamination. All milk samples from the dairy farms were positive for AFM_1, ranging from 0.02–1.5 µg/l. Milk available on the retail market was also frequently contaminated with AFM_1, at levels of 0.01–3.1 µg/l (Dutton *et al.,* 2012; Mulunda and Mike, 2014).

Table 16: Aflatoxin contamination of food and feed in South Africa from 1992–2007

Year	Commodity	Sample size	Aflatoxin concentration (µg/kg)	Reference
1992	Maize	5/118	20	Viljoen *et al.,* 1993
1993	White maize Yellow maize		2 50	Rava *et al.,* 1996
1994/95	Maize	291	< 1–6	Rava, 1996
		156	< 1	
		62 (feed)	< 1	
1996	Baked or boiled areca nuts		0.1	Van der Bijl *et al.,* 1996
	Raw areca nuts	10	3.5–26.2 (mean 8.9)	
1989	Maize (for export to Taiwan)		< 0.5	Rheeder *et al*., 1994
1987	Maize	90	Nil	Marasas, 1988
1999/00	Maize	1/50	22	Anon, 2001
2006/07	Peanut in: KwaZulu-Natal Mpumalanga Limpopo		 ≤ 131 ≤ 160 ≤ 2	Ncube *et al.,* 2010

Summary

In summary, aflatoxin exposure is ubiquitous among the African countries studied, with a wide number of commodities having relatively high levels of aflatoxins far above Codex limits. Variations in aflatoxin exposure that exist between countries are largely a function of diet as well as economic status. An average estimation of exposure rates based on annual consumption, as is appropriate for cancer risk because of the cumulative nature of this response, indicate that aflatoxin exposure was 3.5–14.8 ng/kg/d in Kenya, 11.4–158.6 ng/kg/d in Swaziland, 38.6–183.7 ng/kg/d in Mozambique, 16.5 ng/kg/d in former Transkei South Africa (Eastern Cape), and 4–115 ng/kg/d in The Gambia (Ding *et al*., 2015). The exposure in Ghana, as measured from peanut consumption alone, is estimated to be 9.9–99.2 ng/kg/d (Awuah, 2000). Prevalence testing is needed in other areas where data are not currently available to establish a fuller picture for the country.

3.0 Aflatoxin control in Africa: State of knowledge

3.1 Awareness

Poor awareness about aflatoxins, appropriate control measures to control contamination in the field and in storage, and the negative health effects of aflatoxin consumption are reported in most African countries (Narrod *et al.,* 2011; N'dede *et al.,* 2012; Abt Associates, 2013a; Ephrem *et al.,* 2014). In a study on farmers in Nigeria, out of 2,689 respondents, only 860 (32%) knew what mycotoxins were (Idahor and Ogara, 2010). Other studies have reported similar findings (Ezekiel *et al.*, 2013). In Benin, Ghana and Togo awareness rates have been reported as follows: 20.8% among farmers, 26.7% among traders, 60% among poultry farmers and 25.2% among consumers (James *et al.*, 2007). In a separate study among health workers in Ghana, 80.6% of respondents knew about aflatoxin poisoning through lectures and reading but none had ever told their patients about the risk of aflatoxin ingestion (Ilesanmi and Ilesanmi, 2011). Surveys in Kenya and Mali revealed that most farmers who had heard of aflatoxin obtained that information via local language radio and extension workers, and a lack of understanding contributed to poor control of aflatoxin in the region (Unnevehr and Grace, 2013). In Kenya, households in the drylands, where aflatoxicosis outbreaks occurred in 2004, had a higher perception of risk, as expected, but low knowledge on safety attributes and necessary measures to minimise exposure to aflatoxin. In most parts of Tanzania, knowledge of aflatoxins is low and farmers do not discard aflatoxin-contaminated harvests (Abt Associates, 2013a). Neither do they receive lower prices for aflatoxin-contaminated food since markets do not differentiate between aflatoxin-free and aflatoxin-contaminated food. In Ethiopia, 98.7% of farmers, 96.7% of traders and 70% of consumers were unaware of aflatoxin contamination and its consequences (Ephrem *et al.*, 2014). Moreover, there was no significant difference in responses between farmers (97.3%) and traders (96.7%) in knowledge of long-term exposure to aflatoxigenic fungi and aflatoxin.

Nyangaga (2014) reported that 56.6% of traders in major open markets in Nairobi County were aware of aflatoxin contamination but cattle feed traders were more aware than food traders. Recommendations by Nyangaga (2014) included raising awareness, improving storage facilities and providing guidelines to control aflatoxin levels. Households that are more market-oriented (i.e. sell more than 25% of their produce) and have assets are more willing to pay for aflatoxin risk-reducing technologies in both Kenya and Mali (Tiongco *et al.*, 2011a; Tiongco *et al.*, 2011b; N'dede *et al.,* 2012). In Kenya's drylands, where outbreaks of aflatoxicosis had occurred, respondents were more willing to pay for improved seeds, and tarpaulins and metal silos for drying and storing grain, compared to other regions. Of grave concern, is the fact that there is "*no set 'agenda' for agricultural extension services to include aflatoxins, mycotoxins, food safety, or GAP in their messaging*" (Abt Associates, 2013a), the full adoption of which can contribute to improving farmers' knowledge and awareness on aflatoxin control.

3.2 Traditional practices

In the context of aflatoxin control in Africa, it is important to examine some traditional practices. In Benin, local maize varieties were determined to have lower aflatoxin levels than imported varieties (Hell *et al*., 2008). Planting maize varieties that are less susceptible to fungal growth has been reported to be one of the best methods to help alleviate the effects of mycotoxin-producing fungi (Brown *et al*., 2001). Grains harvested with the husks when mature during dry

weather, and early removal of any damaged maize kernels or cobs, has also been demonstrated to be an effective method for aflatoxin control applied in rural African settings (Hell *et al.,* 2008). Traditionally, sorting was done manually or even through winnowing to get rid of the lighter grains, which were assumed to be lighter due to insect or mould damage. Methods such as visual sorting, winnowing, washing, crushing and dehulling have been found to contribute up to a 40–80% reduction in aflatoxin levels in grains (Whitaker, 2003; Fandohan *et al*., 2005; Waliyar *et al*., 2008a). Sorting is highly recommended for reducing aflatoxin contamination, especially in groundnuts, in countries such as Benin, Ghana and Togo (Park, 2002; Turner *et al.*, 2005; Hell *et al.*, 2008; N'dede *et al*., 2012). Water has also been used to sort grains – allowing floating grains presumed to be damaged to be removed and heavy grains that sink to be cooked. In Kenya and Malawi, soaking and cooking in magadi soda, malting and roasting are other methods that have been used to reduce the levels of aflatoxins in maize (Glaston *et al*., 2000; Makokha *et al*., 2002; Fandohan *et al*., 2005; Mutungi *et al*., 2008).

In Morocco, grapes have been dipped in sieved ash solutions with quicklime salt and water, to prevent rot formation and fermentation (Mazhour, 1983). Some communities in western Kenya use ash to reduce insect pests that have been documented to increase the effects of fungi in maize kernels (Avantaggiato *et al.,* 2003; Munkvold, 2003).

Use of plant products

Many farmers use local plant products, either in their pure form or as oil or water extracts, to control insects during storage. *Ocimum gratissimum*, *Aframonium* spp., *Zingiber officinalis, Xylopia aethiopica, Monodera myristica, Ocimum baslicum, Tetrepleura tetrapeta* and *Piper guineense* have all been tested for their ability to inhibit the mycelia growth of *A. flavus*, while *P. guineense* inhibits the growth of all tested maize pathogens. Essential oils from *Azadirachta indica* and *Morinda lucida* inhibit the growth of toxigenic *A. flavus* and significantly reduced aflatoxin synthesis in inoculated maize grains (Bankole, 1997; Ngueface *et al.,* 2004). Ground *Aframomum danielli* (Zingiberaceae) has been shown to control moulds and insect infestation in stored maize and soybeans for up to 15 months under ambient conditions in southwestern Nigeria (Adegoke *et al.,* 2000). The role of natural botanical products in controlling post-harvest aflatoxin contamination, however, is underdeveloped and under-researched. Further tests are needed to determine inhibition mechanisms and identify the active ingredients of the natural products that inhibit fungal growth for commercialisation.

Fermentation

Fermentation (mainly associated with lactic acid bacteria and yeast) not only improves the taste of food, but has also been shown to increase the availability of specific nutrients and to reduce the accumulation of mycotoxins (Nout *et al.,* 1993; Mokoena *et al*., 2006; Oluwafemi and Da-Silva, 2009; Chelule *et al.*, 2010; Okeke *et al.*, 2015). North and West Africa have a rich tradition of using fermentation to prepare traditional staple foods; maize, millet or sorghum (Ross *et al.,* 1992; Bankole and Adebanjo, 2003; Benkerroum, 2013) and aflatoxin-decontamination effects of fermentation have been documented (Fandohan *et al.*, 2005). In South Africa, sour gruel referred to as *amahewu* and the beverage *Incwana* are cereal-based fermented foods (Chelule *et al.,* 2010). While fermented foods have deep cultural values, their role in mitigating risk from aflatoxin contamination need further study and technological improvements to standardise processes if they are to be promoted widely.

Smoking

Smoking has been used not only to reduce the moisture content in grains, but also to reduce the effects of insects and to act as a fungicide (Daramola, 1986; Hell *et al.,* 2008). In Nigeria, smoking has been applied to reduce moisture content in food crops and meat and has been shown to reduce aflatoxin levels in stored maize and fish (Udoh *et al.*, 2000).

Use of contaminated grains as animal feed

Grains found to be contaminated with aflatoxins were traditionally converted to animal feed by farmers, to minimise financial losses. This practice is not recommended especially given the levels of exposure linked to the consumption of derived products such as contaminated milk as has been previously reported.

4.0 Capacity for detection and quantification of aflatoxins

Specific, sensitive and simple analytical methods for detection and quantification of aflatoxins are needed given their presence in very low concentrations in foods and feed. Accurate determination of the aflatoxin content of a commodity is influenced by the way each step in the evaluation process from sampling to extraction, clean-up and quantification is carried out.

4.1 Sampling framework

The general approach to sampling for aflatoxin testing is by collecting representative samples from which inferences can be made. Variability in results from sampling is much higher than variability in sample preparation and analysis, thus adequate sampling is extremely important (IARC, 2012c). The physical state of samples determines the sampling strategy employed, i.e. whether the sample is a grain, fine or coarse powder, or liquid. Different sampling procedures have been developed to obtain representative samples for laboratory testing. Additionally, several regulatory bodies and agencies provide guidelines on appropriate procedures compliant with regional and international best practices. A manual on effective sampling methodologies for detection of mycotoxins in foods highlights various sources of errors in sampling, including: inadequate sample sizes, biased sampling procedures, inadequate sample comminution, and improper subsampling for analysis (Whitaker *et al.*, 2011).

Sampling grains and flour

Aflatoxin concentrations show a skewed or uneven distribution in whole kernels, making it difficult to collect a sample that accurately represents mean concentration. Thus distribution of ingredients within an analysed sample is a critical aspect (Cheli *et al*., 2012). When sampling grains for aflatoxin testing, it is preferable to take a homogenised sample from harvesting or handling operations. Therefore it is better to sample shelled maize rather than ear maize, and to sample ground maize rather than shelled maize (Davis *et al.,* 1980).

The techniques routinely used to sample grains for aflatoxin analysis include: probe, stream and field sampling, ranked in that order of preference. The choice of sampling technique is dependent on the aim of the sampling exercise. Probe sampling is done using commercially available probes and is appropriate for grains that are properly blended; in sampling a bag of maize, it is better to take portions from top, middle and bottom and combine into a sample. Stream sampling involves taking small portions from a moving stream of grains at periodic time intervals and combining the portions into a sample. Field sampling, coordinated with harvesting, ensures a very large number of maize ears are represented in the sample of shelled maize.

Whenever possible, initial sampling should yield a minimum quantity of 4.54 kg to be ground and passed through a No. 14 sieve, be thoroughly blended, and then properly sub-divided into a 1 kg sample. The 1 kg sample is then ground, passed through a No. 20 sieve, thoroughly blended, and properly subdivided to yield five to nine analytical samples (Ware, 1991). As a rule of thumb a larger sub-sample is required for coarsely-ground material than for finely-ground material.

Cereal millers, middlemen and silos provide large storage facilities that require a sampling plan. However in Africa, smallholder farmers often store their harvest in granaries made out of local plant material that may be iron-roofed. Others store in bricks, either in sacks or

polypropylene bags stacked onto each other. Others still keep unshelled maize grains in stores on the store floor. Sampling in this case can be varied to best suit the situation.

Sampling biological fluids

Bio-monitoring of aflatoxins occurs by analysing the presence of aflatoxin metabolites in blood, milk and urine. Additionally, excreted DNA adducts and blood protein adducts can also be monitored (Bennett and Klich, 2003). When working with human biological materials, the Helsinki declaration and good clinical practice are the cornerstones that form the principles and ethics of samples collection (WMA, 2004). The protocol for sampling and testing should be submitted to an ethical review committee for consideration, comment, guidance and, where appropriate, approval. For research animals, it is a must that their welfare be respected.

Sampling methods to be used to determine AFM_1 levels in milk are specified by the EC Directive (EC, 1998) and Decision (EC, 1991). From a batch of milk mixed by manual or mechanical means, a minimum sample of 0.5 L is collected, composed of at least five increments. The batch is accepted if the concentration of AFM_1 in the sample does not exceed the permitted limit (IARC, 2012c).

EC Directive 2002/98/EC sets quality and safety standards for the collection, testing, processing, storage and distribution of human blood and blood components. Whole blood is collected using blood collection tubes. Urine is collected in clean bottles and kept refrigerated or frozen depending on period of storage before analysis.

4.2 Analytical methods – access and accuracy

Methods for detecting and quantifying aflatoxins in agricultural food crops, feed and samples from human and animal subjects can be grouped as:

1) Chromatographic methods
   a) Thin Layer Chromatography (TLC)
   b) High-Performance Liquid Chromatography (HPLC)
   c) Gas Chromatography (GC)
2) Spectroscopic methods
   a) Fluorescence Spectrophotometry
   b) Frontier Infrared Spectroscopy
3) Immunochemical methods
   a) Radioimmunoassay
   b) Enzyme-Linked Immunosorbent Assay (ELISA)
   c) Lateral Flow Devices (Immunodipsticks)
   d) Immunosensors

Chromatographic methods, such as TLC and HPLC, are the most widely used techniques in aflatoxins analysis and regarded as the official analytical techniques, and are mounted with various detectors. The most recent of these methods use immunoaffinity columns (IACs) for sample extraction and clean-up before HPLC analysis. The highly specific nature of mass spectrometry (MS) eliminates need for extract purification (IARC, 2012c). The development of multi-analyte HPLC-MS/MS methods has enabled analytical chemists to combine analytical steps with a confirmatory test by measuring the mass spectrum of the HPLC peak.

Immunoassays have emerged as better alternatives for routine and on-site detection of aflatoxins. These adapted rapid-screening methods include ELISAs, fluorometric methods, lateral flow devices, and a range of tests that give a yes/no result for contamination above or below a set control level. These methods have been developed for situations where quick decisions are required, such as at granaries, silos and factories (IARC, 2012c). Quantitative or semi-quantitative ELISAs have the advantage of not requiring sample extract purification and can handle many samples in a single experiment. Its disadvantages include cross-reactivity with related mycotoxins, matrix interference problems, possible false positive/negative results and that confirmatory liquid chromatography (LC) analysis is required (Pascale and Visconti, 2008). Some of the very sensitive immunoassay methods require skilled and well-trained operators.

A number of authors have published updates on the developments in mycotoxin analysis covering limit of detections and recovery percentages, and the advantages and disadvantages of various methods (Pascale and Visconti, 2008; Maragos and Busman, 2010; Shephard *et al*., 2011; Shephard *et al*., 2013; Berthiller *et al*., 2014; Wacoo *et al.,* 2014).

In Africa, most researchers use immunoassays, which are considered as screening methods. For more accurate and precise identification and quantification of mycotoxins present, chromatographic methods are used, e.g. HPLC or LC-MS/MS. These methods are not only precise and accurate but they can be used to analyse multiple mycotoxins in a single run whilst using a very simple method for sample preparation (e.g. QuEChERS). Despite these benefits, chromatographic methods require a stable electricity supply and ready availability of special reagents, consumables and spare parts, as well as trained personnel to operate and maintain them. This makes routine use of these analytical methods more likely in well-developed modern laboratories and less likely in laboratories hosted by government-run national institutions in Africa.

4.3 Capacity for aflatoxin determination and quantification

The challenges associated with mycotoxin testing in Africa include lack of political commitment, infrastructure, trained personnel, sustainable supplies, instrument maintenance and repairs, and laboratory quality control and assurance schemes. Considering cost, speed of analysis, availability of personnel and facilities, as well as the characteristics of the tests (sensitivity, specificity and reproducibility) – TLC, HPLC, ELISA and other immunoassays have been identified as the preferred methods for the African region (FAO/WHO, 2005a). Validation of the methods is often carried out by official laboratories or regulatory bodies, and supported by international organisations such as the Association of Official Analytical Chemists and International Organization for Standardization (ISO). In most studies in Africa, direct competitive ELISA procedures are applied unless there is collaboration with foreign laboratories to use the more advanced techniques. The few laboratories that conduct aflatoxin testing using chromatographic methods are costly and are inaccessible to local researchers. Promotion of local development of antibodies and immunoassay kits can help obviate commercial costs, but caution needs to be exercised in maintaining quality of such kits.

Laboratories under the CGIAR Consortium are well equipped and have highly-skilled staff who carry out mycotoxin testing. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), a CGIAR centre, has developed a simple, robust, versatile, low-cost, effective competitive ELISA (cELISA) test for the detection of aflatoxin (ICRISAT, 2009). The

CGIAR centres have the benefit of favourable funding, which supports the development of their diagnostics capability. The International Livestock Research Institute (ILRI), for example, through an Australian Agency for International Development (AusAID) funded project has established an aflatoxin research and capacity-building platform at the Biosciences eastern and central Africa (BecA-ILRI) Hub in Nairobi, Kenya, which is open to biosciences researchers focused on improving food security in Africa. At the platform there is a laboratory team working to develop new aflatoxin diagnostics, such as the electronic nose, that are more suited to the African context. Another technology being worked on at the BecA-ILRI Hub is Near Infrared (NIR) to predict the presence of aflatoxin in samples. NIR is supplied by South Africa-based Bruker® who offer technical support. Compared to other African countries, South Africa is advanced in aflatoxin-testing technology and is well equipped. NIR, if operational, will be non-destructive, requiring no sample preparation or extraction solvents, making it quick and reliable for quantitative and qualitative analysis. However, a need still exists for methods that are applicable to small-scale farms, where resources are limited and rapid decisions are needed concerning contamination (Harvey *et al.*, 2013).

5.0 Regional collaboration and mitigation activities

Food safety can only be guaranteed by policies and legislation that safeguard consumers, minimise economic and health risks, and ensure functioning of food markets in an orderly manner (Jabbar and Delia, 2012). Many African countries have established food laws and regulations mainly based on Codex Alimentarius standards to allow exports to be accepted in different international markets (Mutasa and Nyamandi, 1998). Crop exports from Africa cannot easily access European markets due to the strict sanitary and phytosanitary requirements imposed on their products (Otsuki *et al*., 2001). Standards still remain important barriers to trade (Bhat and Vashanti, 1999; Rios and Jaffee, 2008; Unnevehr and Grace, 2013).

Standards for 'acceptable' aflatoxin levels in food vary widely across African countries, from 0–50 ppm. Studies on the status of food and feed safety legislations in Africa identified significant gaps, inadequate linkages between strategies, and outdated and overly prescriptive laws that failed to address a whole range of food safety concerns (FAO/WHO, 2005a; Jabbar and Delia, 2012; Hell, 2015). Failure to meet standards for aflatoxin have had a negative impact on African trade, with a loss of up to US$750 million annually (Jabbar and Delia, 2012). Africa's inability to meet the regulatory standards set by many importing countries, especially the EU, is cause for concern. PACA, in collaboration with regional economic communities (RECs), is working toward improving the enabling policy and institutional environments to support countries to update and harmonise legislation (Waliyar *et al*., 2008b; Ayalew *et al*., 2013), to enforce standards and maintain larger trading blocks that can negotiate with importing countries and larger bodies, such as the World Trade Organization.

5.1 Regional trading blocks

There are 14 RECs in Africa that are officially recognised by the African Union (AU), some of which overlap in membership (Hell, 2015). The RECs include Arab Maghreb Union, Commutė Economique et Monėtaire des Etats de l'Afrique Central (EMAC), Communautė de EtasSahėlo Sahariens, Common Market for Eastern and Southern Africa (COMESA), the East African Community (EAC), Economic Community of Central African States (ECCAS), Economic Community of West African States (ECOWAS), South Africa Development Community (SADC), Southern Africa Customs Union (SACU), and Union Economique et Monėtaire Quest Africaine (UEMOA). Aflatoxin contamination undermines the free trade agreements of RECs in Africa.

ECOWAS

ECOWAS is a regional integration group of 15 member countries, eight of which have food safety legislation in place (Hell, 2015). Only Benin, Ghana and Nigeria have specific standards for aflatoxin while the other five use Codex limits as required by major trading partners (Hell, 2015). Most research data on levels of aflatoxins and affected commodities have been collected from Benin, Ghana and Nigeria, but smaller studies have occurred in Burkina Faso, Côte d'Ivoire, The Gambia, Guinea, Mali, Senegal and Togo. Little or no research has been documented from other countries including Cape Verde, Guinea-Bissau, Liberia, Niger and Sierra Leone. ECOWAS countries are at different levels on instituting GAP to reduce mycotoxin through post-harvest and processing interventions. Examples include the use of good practices and Purdue Improved Crop Storage (PIC) bags; good post-harvest practices

in maize (Guinea); special sorting of groundnut to reduce aflatoxin; screening technology; and reduction of post-harvest losses of grains and pulses (Hell, 2015).

Some Western and Central African countries have also set up food testing laboratories under the French Protocol which is an agri-food quality programme (Tulasne, 2002). Twenty-three laboratories are currently participating in the regional network, creating openings for product certification for national, regional and international markets.

UEMOA

UEMOA is a regional organisation of eight francophone (Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Mali, Niger, Senegal and Togo) countries in West Africa that share a common currency. A programme of SPS harmonisation began in early 2003, focusing on the preparation of a legislative framework and associated treaties, training of officials to interpret and implement the treaties, and strengthening of quality control laboratories. With EU support, UEMOA established legal and regulatory frameworks for food safety; a regional certification scheme and harmonisation of 36 national standards; enhanced the competitiveness of enterprises that complied with international trade rules and technical regulations; and developed national and regional infrastructure for quality, standardisation and conformity assessment.

SADC

SADC represents 15 member states (Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mauritius, Madagascar, Malawi, Mozambique, Namibia, Seychelles, South Africa, Tanzania, Zambia and Zimbabwe). There is good cooperation over food contamination emergencies in SADC. Varying laboratory capacities have been identified between member states, so the upgrading of existing facilities into regional centres of excellence has been recommended (FAO/WHO, 2005b). Some countries are sharing facilities amongst several states as a more cost-effective and sustainable arrangement to deal with the problem of poor laboratory facilities.

The SADC Secretariat has carried out a number of activities aimed at improving the capacity of member states to implement the SPS Annex to the SADC Protocol on Trade. The activities were funded through an EU-sponsored Regional Economic Integration Support programme.

In Malawi, Mozambique and Zambia – with collaborators from the USA and UK – the Peanut and Mycotoxin Innovation Lab) 5-year project, which is expected to end in 2017 is implementing aflatoxin management interventions, education, and analysis at various steps along the peanut value chain; production, post-harvest handling, and processing issues that impact aflatoxin contamination levels, yield and profitability.

EAC

EAC represents six states in Eastern Africa (Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda). Several workshops have been held to raise awareness and build capacity on aflatoxin control in the EAC. The United States Agency for International Aid Development (USAID) is very active:

- USAID Leveraging Economic Opportunities (LEO) project is evaluating SPS trade policy constraints within the maize and livestock/animal-sourced products value chains in Eastern Africa.
- USAID's Feed the Future initiative: capacity building activities with the EAC to strengthen laboratory diagnostics and quality assurance, as well as methods to augment surveillance for plant disease and control of product contaminants such as aflatoxin.

Technical assistance activities that are addressing aflatoxin include:

- The Kenya-based East Africa Trade and Investment Hub project funded by the USAID regional mission developed harmonised guidelines for sampling, testing and grading procedures and methods for the East African States 2013 Staple Food Standards. The programme – Development Alternatives Inc. Trade Africa: East Africa Trade and Investment Hub (2014–2019) – has several project goals, including a strong SPS initiative to increase EAC inter-regional trade in staple foods by 40%. The project builds on the policy environment with EAC integration in trade and investment.
- Developed and implemented in Kenya, the International Food Policy Research Institute (IFPRI)-run 'Aflacontrol Survey', which targeted maize (Kenya) and groundnut (Mali) was funded by the Bill and Melinda Gates Foundation (BMGF).
- The 'Aflastop Storage Drying for Aflatoxin Prevention' maize storage and drying programme, funded by USAID and BMGF, offered farmers and traders practical technological options to store and minimise the risk of aflatoxin contamination.
- BMGF also funded research to create a low-cost diagnostics test for aflatoxin. The aflatoxin test-kit was piloted in 2013 but funding was not sustained.
- Run by the International Institute for Tropical Agriculture (IITA), the Aflasafe project develops and tests biological control products for 11 sub-Saharan African countries and has developed and proposed protocols for aflatoxin sampling in maize and groundnuts which are being piloted. The project is also assisting the World Bank's AgResults Aflasafe commercialisation pilot in Nigeria. Funded by BMGF, through PACA, the project also leverages funds from several other donors including USAID and United States Department of Agriculture (USDA).

COMESA

COMESA represents 19 member states (Burundi, the Comoros, DRC, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Sudan, Swaziland, Seychelles, Uganda, Zambia and Zimbabwe). Maize traded in the COMESA region is duty free, but borders are often closed if there is a perceived shortfall of the crop in exporting countries. Aflatoxins in COMESA countries therefore challenge regional and international trade. COMESA, in collaboration with the Kenya Plant Health Inspectorate Services, has worked towards the harmonisation of aflatoxin sampling and testing protocols in the region through capacity building (28–29 February 2012, Nairobi, Kenya). The aim was to develop a regional action plan to lead to agreed regional protocols for aflatoxin sampling and testing procedures (Byanyima, 2012b). Another workshop in Uganda in 2013 and supported by USDA, established priorities for SPS capacity building using Multi-criteria Decision Analysis. A 2014 African Agriculture Technology Foundation (AATF)/AUC/COMESA/IITA/PACA/ USAID regional workshop looked at the challenges posed by aflatoxins and opportunities to improve health, trade and food security through regional efforts to mitigate aflatoxin contamination.

A major achievement of COMESA has been the creation of the tri-partite free trade area (FTA), by merging EAC, COMESA and SADC FTAs. The tri-partite FTA agreement laid out a legally binding coordination mechanism to enable the three RECs to harmonise SPS programmes and implement risk-based SPS measures, ensuring smooth flow of food and agricultural products across the tri-partite region.

The coordination of activities of regional bodies in relation to aflatoxin control is challenging given the overlapping mandates, yet the efforts by PACA to harmonise regulations can possibly lead to sustainable outcomes and greater impact. Coordinating legislation and standards is currently under way to address aflatoxin control across the value chain by enforcing GAP and paying attention to production practices by smallholder farmers. However equal attention should also be given to the adoption and implementation of good manufacturing practices to reduce the levels of aflatoxin in contaminated foods and feed.

5.2 Mitigation activities: Feasibility of interventions and uptake in Africa

Aflatoxin mitigation requires a multifaceted approach since contamination can take place anywhere along the value chain. Mitigation interventions can be primary, targeting the prevention of the occurrence of the toxins in food and feed, or secondary, which attempt to prevent exposure of humans and animals to the toxins after ingestion of contaminated food or feed. Developing mitigation strategies for the prevention or reduction of aflatoxins requires a good understanding of the factors that influence the infection process and the conditions that influence toxin formation.

Soil type and condition, and the availability of viable spores, are important factors. Environmental factors that favour *A. flavus* infection in the field include high soil and/or air temperature, drought stress, nitrogen stress, crowding of plants and conditions that aid the dispersal of conidia during silking (Diener *et al*., 1987). Factors that influence the incidence of fungal infection include presence of invertebrate vectors, grain damage, oxygen and carbon dioxide levels in stores, inoculum load, substrate composition, fungal infection levels, prevalence of toxigenic strains, and microbiological interaction (Horn, 2003). Crop rotation and management of crop residues are also important in controlling *A. flavus* infection in the field. Significant inroads are being made in establishing various promising pre- and post-harvest control strategies in Africa.

5.3 Primary interventions

Pre-harvest management strategies

Pre-harvest technologies are seen as the most promising, cost-effective and easy-to-use technologies for farmers (Bhatnagar-Mathur *et al.*, 2015). A combination of strategies is needed to adequately prevent mycotoxin contamination in the field. Plants may be developed that resist fungal infection and/or reduce the toxic effects of the mycotoxins themselves, or interrupt mycotoxin biosynthesis.

Breeding

Plant resistance is generally considered a highly desirable approach to reducing or eliminating *A. flavus* infection and subsequent accumulation of aflatoxin. Potential biochemical and

genetic resistance markers have been identified in crops, particularly in maize, and are being utilised as selectable markers in breeding for resistance to aflatoxin contamination. Efforts to enhance plant resistance to aflatoxin contamination have mainly focused on the fungus, inhibition of aflatoxin production and resistance to insects, and drought tolerance, by applying both conventional and transgenic technology. Gene clusters housing the genes governing formation of aflatoxins have been elucidated and are being targeted in strategies to interrupt the biosynthesis of these mycotoxins. The focus on resistance to insects and drought tolerance is because of a suggested correlation between them and aflatoxin contamination in some studies.

Various programmes funded by the International Maize and Wheat Improvement Centre (CIMMYT) are screening maize germplasm for resistance to aflatoxin accumulation in Africa. The University of Nairobi, Kenya Agricultural and Livestock Research Organization (KALRO), Stellenbosch University and the Agricultural Research Council, funded by CIMMYT, have screened inbred lines from Kenya and South Africa for resistance to aflatoxin and fumonisin accumulation. Breeding trials with inbred lines identified as having low susceptibility to *Aspergillus* ear rot and aflatoxin accumulation are ongoing. The Agricultural Research Council of South Africa is also carrying out separate trials. ICRISAT has also reported new peanut varieties with low pre-harvest aflatoxin contamination (Nigam *et al*., 2009).

In Malawi and Tanzania, the McKnight Foundation and Collaborative Crop Research Programme-funded groundnut breeding programme worked from 2010 to 2013 to identify lines with low aflatoxin contamination. In Malawi the project was implemented by ICRISAT, the National Agricultural Research Services and the National Smallholder Farmers' Association of Malawi, while in Tanzania it was implemented by Naliendele Agricultural Research Institute.

ICRISAT has reported the following breeding lines to be resistant to *A. flavus* seed infection and colonisation: ICGVs 87084, 87094, 87110, 91278 and 91284. The following peanut cultivars have shown stable resistance to *A. flavus* across locations: J 11, 55-437, and PI 337394F. Some of these breeding lines also possess aflatoxin resistance and are also high yielding. Efforts have been made to develop aflatoxin-resistant transgenic peanut plants (Waliyar *et al.*, 2015) as an effective long-term genetic approach to the problem.

For maize, the transgenic approach has focused mainly on expression of recombinant insecticidal proteins from *Bacillus thuringiensis* (Bt), expression of antifungal peptids and proteins, and the use of Host Induced Gene Silencing technology. No product is currently on the market except for Bt maize which is grown only in South Africa where it was approved for commercial use in 1998 (Marnus *et al*., 2006). Conflicting reports have been documented on the ability of Bt toxin technology against the European corn borer to reduce aflatoxin levels in maize. One study has shown no significant effect of Bt maize while other studies have shown mixed results (Wu*,* 2007; Ostrý *et al*., 2015). The effect Bt maize has on lowering levels of aflatoxins is not pronounced compared with fumonisins and this should be expected because of the different infection pathways of the fungi producing these toxins. These data therefore require further research studies to be conclusive (Diaz-Gomez *et al*., 2016). The development of transgenic plants expressing genes that protect against fungal infection, for example, would be a more effective strategy.

Environmental stresses, such as drought and heat, have been shown to promote aflatoxin production through the accumulation of reactive oxygen species within the host plant tissues,

which in turn initiate toxin production by *A. flavus* (Chen *et al*., 2004; Guo *et al*., 2008; Fountaina *et al*., 2015). Drought- and insect-resistant maize and groundnut varieties have been reported to have relatively lower pre-harvest aflatoxin contamination than the check cultivars in other parts of the world (Holbrook *et al.*, 2000; Tubajika and Damann, 2001; Guo *et al*., 2008; Williams *et al*., 2015). Breeding for stress-tolerant cultivars is therefore seen as another strategy for management of aflatoxins. CIMMYT, jointly with IITA, launched the 'Drought Tolerant Maize for Africa' (DTMA) project in 2006 to work in close collaboration with national agricultural research systems in participating nations to mitigate drought and other constraints to maize production in sub-Saharan Africa. DTMA has released several such drought tolerant varieties in 13 African countries (CIMMYT, 2015).

Biocontrol

Atoxigenic biocontrol of *A. flavus* that can outcompete closely related, toxigenic strains in field environments, consequently reducing levels of aflatoxins in crops, is commercially packaged and sold as Aflasafe™. IITA, in partnership with the USDA–Agricultural Research Service and AATF developed Aflasafe™, which is already registered in Kenya and Nigeria. IITA has reported consistent reduction of aflatoxin contamination in maize and groundnuts by 80–90%. The product is ready for registration in Burkina Faso and Senegal and is being tested in Zambia. Trials are being expanded in Ghana, Malawi, Mali, Mozambique, Tanzania and Uganda. In Kenya and Burkina Faso, IITA has identified separate sets of four competitive atoxigenic strains isolated from locally-grown maize to constitute a biocontrol product called aflasafeKE01™ and aflasafe-BF01, respectively (IITA, 2012). The use of other organisms, such as bacteria and yeasts, as biocontrol agents are still under experimentation (Aliabadi *et al*., 2013). Wu and Khlangwiset (2010) describe the use of pre-harvest Aflasafe™ in Nigeria and post-harvest management in Guinea as cost-effective in terms of improved health outcomes: the monetised value of lives saved and quality of life gained by reducing aflatoxin-induced hepatocellular carcinoma compared with the cost of the two interventions. However, the long-term consequences of the use of these biocontrol products to both farmers and the environment have been questioned (Ehrlich, 2014; Ehrlich *et al.,* 2014).

Good Agricultural Practices (GAP)

GAP aims at reducing the load of the fungus in soil, reducing environmental stresses on plants and ensuring growth of healthy plants. The following practices are being promoted to reduce aflatoxin contamination: selection of healthy seeds, early planting, avoidance of mono-cropping, treatment of foliar diseases, application of lime or gypsum, mulching, maintenance of optimal density of plants in the field, avoidance of end season drought through irrigation, and removal of dead plants from the field before harvest (Waliyar *et al*., 2013).

Post-harvest management strategies

Although aflatoxins can contaminate commodities anywhere along the value chain, dramatic increase is normally observed in storage. Crop management practices at harvest and post-harvest are an effective way of avoiding, or at least diminishing, infection by *A. flavus* and subsequent aflatoxin contamination. These include, harvesting at maturity, avoidance of damage of kernels, rapid drying on platforms to avoid contact with soil, drying seeds to 8% moisture level, appropriate shelling methods to reduce grain damage, sorting, use of clean and aerated storage structures, control of insect damage, and avoidance of long storage

periods. Several methods and tools are being promoted and tested in collaboration with farmers in Africa. Examples are outlined below:

Storage and drying options by AflaSTOP

The AflaSTOP project in Kenya is testing storage and drying devices to reduce aflatoxin accumulation on smallholder farms (ACDI/VOCAb, 2015). Three different storage devices are currently being evaluated for commercialisation: GrainPro Grain Safe II manufactured by GrainPro; metal silos made out of aluminium by local artisans; and Purdue Improved Crop Storage initially introduced to West Africa by Purdue University and currently manufactured in Kenya by Bell Industries Metal Silo. Hermetic bags have also been used by ICRISAT in Mali and GrainPro company is now manufacturing them in Kenya (Villers, 2015).

AflaSTOP is testing the shallow bed dryer, which is reportedly showing promising results. It is a completely new device that has never gone on the market. The basic configuration of this mechanical dryer is a furnace, a heat exchanger and a supply of air (provided by fan). The heat from the furnace moves through the heat exchanger and through the raised bed that contains the grain. Mobile maize dryers are already being used by grain handlers in Kenya (Wanjiru, 2011).

Storage methods by Cultivate Africa's Future

CultiAF is a joint programme of the Australian International Food Security Research Centre and Canada's International Development Research Centre. The project is testing the efficacy of air-tight metal storage silos and thick plastic 'super bags' for storing grains to reduce aflatoxin accumulation in maize grains (ACIAR, 2015).

Storage practices to reduce aflatoxin contamination

IFPRI worked with households in Meru, Kenya, to test the effect of inexpensive improved post-harvest and storage practices on aflatoxin contamination of maize and the effect of reduced consumption of contaminated maize on growth of children under 2 years by swapping contaminated maize with clean maize (Hoffmann *et al.*, 2014). The results were positive.

Sorting options

Electronic devices such as Near-Infrared Hyperspectral Imaging and high-speed dual-wavelength sorters have been tested to remove maize and peanuts contaminated in the field with aflatoxin (Pearson *et al*., 2004; Wei *et al.*, 2015). These methods are expensive and not suitable for smallholder farmers.

Detoxification and decontamination

Segregation and detoxification of aflatoxin-contaminated commodities has been suggested. In Malawi segregation of aflatoxin-contaminated peanuts by visual or mechanical means has been attempted. In Senegal and Sudan, industrial detoxification of aflatoxin-contaminated peanut oilseed cake by processes such as ammonia and formaldehyde treatment are in place (Grenier *et al.*, 2012). Industrial plants with decontamination capacities ranging from 0.5 t to 600 t are in operation (Bhat, 1991). However, such products (detoxified seed cakes) are useful only as animal feed and the possible deterioration of animal health by excessive residual

ammonia in the feed remains a concern and regulatory measures permitting the marketing of such detoxified products have yet to be formulated.

Detoxification of crude oil by binding aflatoxin in groundnut oil and cake has been presented as a possible method for use at the small-scale industry or household level (Mehan, 1995). The use of red clays in West African countries has been found to be effective in binding aflatoxin in contaminated groundnut cake. In Senegal, it was found that exposure to sunlight for 18–24 hours in transparent and translucent containers destroyed 100% of the toxin in contaminated oil (Kane, 1996). The method is simple and is suggested for use by oil processors at the village level. Other aflatoxin management initiatives are listed in Table 17.

Table 17: Aflatoxin management and reduction projects in Africa

Project initiative	Country of implementation	Project objective	Project link/references
Feed the Future Innovation Lab	Malawi, Mozambique, Zambia	Technologies along the peanut value chain, and education	http://pmil.caes.uga.edu/research/NCSU202/index.html 2013–2017
Platform for African European Partnership on Agricultural Research for Development (PAEPARD)-CRF project	Malawi	Practices in peanut farming, knowledge management, and policy	http://www.fanrpan.org/documents/d01766/ 2014–2017
Safe Food Safe Dairy, Government of Finland	Kenya	GAP	http://safefood.uonbi.ac.ke/
Food Africa, Government of Finland	CGIAR Research Programme in Benin, Ghana, Cameroon, Kenya, Senegal, Uganda		https://portal.mtt.fi/portal/page/portal/mtt_en/projects/foodafrica
World Food Programme	Uganda	Technologies along maize value chain, and education	http://documents.wfp.org/stellent/groups/public/documents/special_initiatives/WFP265205.pdf 2013–2014
Flemmish Interuniversity Council-Insitutional University Cooperation (VLIR-UOS) funded project 2011–2016	Tanzania	Effective strategies for minimising exposure of mycotoxins in maize based complementary foods in Tanzania	Kamala *et al*., 2015; Kamala *et al*., 2016

Diagnostics for aflatoxin detection

Testing contaminated lots of commodities can be seen as a post-harvest technology that can be used to manage aflatoxin exposure. A set of diagnostic solutions is required that can be

used by both smallholder and commercial farmers in the field during harvest, in village and commercial mills, and in silos. These should be inexpensive and portable. A number of initiatives seek to address the lack of diagnostic tools characterised by a few inaccessible laboratories. Some of these include Agristrips, Dipstrips and E-nose, but none are being used by smallholder farmers. In Kenya the Aflatoxin Proficiency Testing and Control in Africa (APTECA) programme, hosted by the mycotoxin diagnostics platform at the BecA-ILRI Hub, is contributing to the availability of safe maize on the market through partnership with the commercial maize milling sector. APTECA trains millers in sampling and testing and provides routine proficiency testing and verification of mill results by the ISO accredited Texas A&M AgriLife laboratory housed at the BecA-ILRI Hub (Herman, 2016).

5.4 Secondary interventions: Adsorbents/binders

Addition of adsorbents (also named binders or sequestering agents) to livestock and poultry feed is practiced in Africa. These agents bind aflatoxins in the gastrointestinal tract and are capable of reducing its availability (Huwig *et al.*, 2001; Phillips *et al.*, 2002). Research with mycotoxin binders has been conducted for over 20 years with strong evidence about the performance of some of them. Substances used as mycotoxin binders include indigestible adsorbent materials such as silicates, activated carbons, and complex carbohydrates. Several of these adsorbent materials are recognised as safe feed additives and are used as flow agents and pellet binders, but not specifically as aflatoxin binders or for treatment of aflatoxicosis (Grenier and Applegate, 2015).

Use of binders in humans has been suggested for Africa and trials have been carried out with human subjects in Ghana (Phillips *et al.*, 2008), and as recently as 2015 in eastern parts of Kenya by the Centre for Disease Control (Awuor *et al.,* 2016). However the binding capacity of adsorbents has raised controversial questions regarding their influence on the utilisation of nutrients such as carbohydrates, proteins, vitamins and minerals, and their use in human diets has stirred even more reactions.

Diversifying diets and consumption of probiotics have been promoted to reduce aflatoxin exposure (Liu and Wu, 2010; Nduti *et al*., 2016). The synergistic effect of Hepatitis B Virus (HBV) and aflatoxin in inducing hepatocellular carcinoma by thirty-fold has been documented (Groopman and Kensler, 2005). HBV vaccination has also been seen as a practical intervention for reducing the risk of aflatoxin-induced liver cancer and cirrhosis (Kuniholm *et al.*, 2008).

6.0 Conclusion

This literature review demonstrates that a wide range of commodities that are produced in Africa and traded domestically, regionally and internationally are contaminated with aflatoxins. Commodities can be attacked by the *Aspergillus* sp. anywhere along the value chain and once infected the aflatoxins remain. No single technology or intervention emerges as a standalone strategy for wide-scale adoption in Africa. Each has its unique benefits and drawbacks. The report also demonstrates that significant investments have been made, especially by the research, academic and donor community, in investigating the aflatoxin challenge and exploring possible solutions to control contamination, with varying measures of success. However, despite the vast knowledge base, the challenge of controlling aflatoxin contamination persists, with continued negative impacts on human health, agri-businesses, trade and socio-economic development.

A major factor that contributes to the pronounced exposure to aflatoxins in humans (as well as livestock, including farmed fish) in Africa, is the wide range of agro-ecological conditions, temperature and humidity, which favour the growth of *Aspergillus flavus*, *A. parasiticus* and other *Aspegillus* species. This is further complicated by the fact that the variety of cereals and other crops (roots and tubers, spices, legumes) that are contaminated in the field or in storage by the *Aspergillus* fungi are essential staple foods for a majority of Africans. For example aflatoxin levels as high as 138,000 µg/kg have been reported in pre-harvest maize samples in Nigeria and 48,000 µg/kg in stored maize. Contaminated crops are also used to produce a range of processed products (e.g. peanut butter and local brews) and animal feeds, resulting in both food and feed being contaminated.

In Africa, contamination levels of foods and feeds commonly exceed internationally acceptable standards. Aflatoxins found in feeds can also be efficiently converted to toxic metabolites in milk, meat and eggs. No country is immune and African consumers and livestock remain at risk. Exposure levels have been found to be up to 1,064 pg/mg aflatoxin albumin levels in blood samples based on biomarker studies, although this analytical technique is relatively new.

Apart from causing acute poisoning and death at high doses in both humans and animals, at chronic lower-level doses aflatoxins cause liver cancer, immunomodulation, stunting and kwashiorkor in young children. Reports of death resulting from severe aflatoxin poisoning and/or presence of aflatoxins in organs have been reported in both humans and animals in Kenya, Nigeria, South Africa, Tanzania and Uganda. The effects of chronic exposure cannot be quantified, but correlation with stunting in children in West Africa has been reported. Liver cancer causes about 26,000 deaths annually in sub-Saharan Africa. Ample evidence of other effects on humans due to chronic exposure have been deduced from animal studies.

Awareness of aflatoxins and the associated risks among African consumers and value chain actors (e.g. farmers, traders) is low. Knowledge is only high in areas where outbreaks have occurred and more so among educated populations. Inclusiveness of actors along commodity value chains in the fight against aflatoxins is imperative. Investing in public education and designing and implementing an effective communication strategy along value chains must be a priority for countries in the fight against aflatoxins. Studies have shown that consumers and buyers (processors, traders, exporters) are willing to pay a premium for aflatoxin free products. The premiums, however have to ensure that a wider cross-section of Africans can purchase

safe food at affordable prices; the demographic data shows that poorer people are more exposed and at greater risk.

There is little evidence that the biology of the *Aspergillus sp.* under diverse environmental conditions and the prevailing context of smallholder farming systems is well understood and applied in developing new technologies and piloting innovative solutions to control aflatoxin contamination in Africa. Adopting GAPs and controlling moisture content, especially during storage and transport, have been shown to be very effective in managing fungal growth and aflatoxin contamination and must be promoted widely in Africa. Farmers should be the primary target group in the fight against aflatoxin contamination in Africa. They need to be empowered with knowledge and appropriate technologies and given incentives and rewards for adopting good practice.

The report points to promising pre-harvest innovations that depend on the manipulation of the fungal population ecology (e.g. Aflasafe^{TM}), and reproduction and gene manipulation (e.g. breeding for resistance), but consideration should be given to the potential environmental impact of these products. For example, the possibility of atoxigenic biocontrol strain acquiring aflatoxin pathway genes through vegetative fusion and sexual reproduction could exacerbate the aflatoxin contamination problem. Breeding of *Aspergillus* Ear Rot-resistant maize to reduce aflatoxin and fumonisin accumulation is widely accepted as a safe and easy-to-use option. However, the aflatoxin resistant genes are polygenic, therefore requires gene pyramiding using numerous genotypes with novel genes which could take many breeding seasons to come up with a resistant variety. Greater knowledge of gene function and expression under a range of environmental conditions is a necessity given the knowledge of host-induced environmental reactions. Further, some of the resistant varieties are not adapted to, or do not yield well in the agro-ecologies endemic to aflatoxin contamination in Africa.

Weak governance and legislative framework is a major drawback in the fight against aflatoxins. Enforcement of regulations at every stage of a commodity's value chain is not possible, especially because small-scale farming systems and informal markets and trade predominate. The ideal workable situation is for countries to develop and apply stringent standards and enforce regulations backed by GAPs and appropriate sampling and testing to drive innovations to control aflatoxin contamination, as is the case in developed countries. Country governments are encouraged to invest in building certified and accessible infrastructure for training manpower, and testing and grading commodities. Another option is to provide incentives such that all enterprises (small, medium and large) can self-regulate to ensure conformance with relevant local, regional and international standards. However, absence of standards and ineffective implementation of regulations is not an option if Africa is to effectively address the aflatoxin challenge.

Harmonisation of legislation within trading blocks and strictness in upholding the rules will also contribute to mitigation of aflatoxin contamination. While international exports are easier to control (as recipient countries have well equipped accredited testing laboratories to ensure adequate enforcement and limit what comes into their countries), Africa must seek to do the same. This will give Africa a competitive advantage as the EU and other major trade partners lower the tolerable limits for aflatoxins and regulations and enforcement becomes stricter.

References

Abalaka, J.A. and Elegbede, J.A. 1982. 'Aflatoxin distribution and total microbial count in an edible oil extracting plant 1: Preliminary observations'. *Food and Chemical Toxicology* 2: 43–46.

Abdel-Hafez, A.I.I. and Saber, S.M. 1993. 'Mycoflora and mycotoxin of hazelnut (*Corylus avellana* L.) and walnut (*Juglans regia* L.) seeds in Egypt'. *Zentralblatt für Mikrobiologie* 148 (2): 137–147.

Abdel-Rahim, A.M., Osman, N.A. and Idris, M.O. 1989. 'Survey of some cereal grains and legume seeds for aflatoxin contamination in the Sudan'. *Zentralblatt für Mikrobiologie* 144 (2): 115–121.

Abdulrahaman, A.A. and Kolawole, O.M. 2006. 'Traditional preparations and uses of maize in Nigeria. *Ethnobotanical Leaflets* 10: 219–227.

Abdus-Salaam, R., Fanelli, F., Atanda, O., Sulyok, M., Cozzi, G., Bavaro, S., Rudolf, K., Logrieco, A.F. and Ezekiel, C.N. 2015. 'Fungal and bacterial metabolites associated with natural contamination of locally processed rice (*Oryza sativa* L.) in Nigeria'. *Food Additives & Contaminants* 32 (6): 950–959.

Abegaz, M. 2004. ''Gap analysis report, recommendations and proposals on food control system in Ethiopia. UNIDO's regional programme on harmonization of food control system in East Africa, December 2003, Addis Ababa'. Paper presented at the regional workshop on *Regional Harmonization of Food Safety and Quality System in East Africa*, 25–27 February 2004, Kampala, Uganda.

Abia, W.A., Warth, B., Sulyok, M., Krska, R., Tchana, A., Njobeh, P.B., Turner, P.C., Kouanfack, C., Eyongetah, M., Dutton, M. and Moundipa, P.F. 2013 'Bio-monitoring of mycotoxin exposure in Cameroon using a urinary multi-biomarker approach'. *Food and Chemical Toxicology* 62: 927–934.

Abiala, M.A., Ezekiel, C.N., Chukwura, N.I. and Odebode, A.C. 2011. 'Toxigenic *Aspergillus* section *flavi* and aflatoxins in dried yam chips in Oyo state, Nigeria'. *Academia Arena* 3 (5): 42–49.

Abt Associates. 2012a. *Aflatoxin Contamination and Potential Solutions for its Control in Nigeria*. A summary of the country and economic assessment conducted in 2012 at the Aflatoxin Stakeholder Workshop, 5–6 Novemebr 2012, Abuja, Nigeria. Abt Associates, Bethesda, USA.

Abt Associates. 2012b. *Literature Review to Inform the Aflatoxin Country Assessments: Tanzania and Nigeria*. Prepared for the Meridian Institute in support of the Partnership for Aflatoxin Control in Africa (PACA). Abt Associates, Bethesda, USA.

Abt Associates. 2013a. 'Aflatoxin contamination and potential solutions for its control in Tanzania'. A summary of the country and economic assessment conducted in 2012 at the *Aflatoxin Stakeholder Workshop*, 3–4 December 2012, Dar es Salaam, Tanzania. Available at: http://www.aflatoxinpartnership.org/uploads/Tanzania%20Policy%20Brief.pdf

Abt Associates. 2013b. *Country and Economic Assessment for Aflatoxin Contamination and Control in Tanzania*. Preliminary Findings. Prepared for the Meridian Institute in support of the Partnership for Aflatoxin Control in Africa (PACA). Abt Associates, Bethesda, USA.

ACDI/VOCA. 2015a. *Kenya Maize Development Program (KMDP)*. ACDI/VOCA, Washington, DC, USA.

ACDI/VOCA. 2015b. 'Kenya Storage and Drying for Aflatoxin Prevention Project (AflaSTOP)'. *ACDI/VOCA* [online]. Available at: http://52.0.15.52/our-programs/project-profiles/kenya-storage-and-drying-aflatoxin-prevention-project-aflastop

Ackah, C. and Aryeetey, E. 2012. *Globalization, Trade and Poverty in Ghana*. International Development Research Centre (IDRC), Ottawa, Canada.

Adebajo, L.O, Idowu, A.A. and Adesanya, O.O. 1994. 'Mycoflora and mycotoxins production in Nigerian corn and corn-based snacks'. *Mycopathologia* 126: 183–92.

Adebayo-Thato, B.C. and Etta, A.E. 2010. 'Microbiological quality and aflatoxin B1 level in poultry and livestock feeds'. *Nigerian Journal of Microbiology* 24 (1): 2145–2152.

Adegoke, G.O., Allamu, A.E., Akingbala, J.O. and Akanni, A.O. 1996. 'Influence of sun drying on the chemical composition, aflatoxin content and fungal counts of two pepper varieties: *Capsicum annum* and *Capsicum frutescens*'. *Plant Foods in Human Nutrition* 49 (2): 113–7.

Adegoke, G.O., Iwahasi, H., Komatsu, Y., Obuchi, K. and Iwahasi, Y. 2000. 'Inhibition of food spoilage yeasts and aflatoxigenic moulds by monoterpenes of the spice *Aframonium danielli'*. *Flavour and Fragrance Journal* 15: 147–150.

Adejumo, O., Atanda, O., Raiola, A., Somorin, Y., Banadyopadhyay, R. and Ritieni, A. 2013. 'Correlation between aflatoxin M_1 content of breast milk, dietary exposure to aflatoxin B_1 and socioeconomic status of lactating mothers in Ogun State, Nigeria'. *Food and Chemical Toxicology* 56: 171–177.

Adetuniji, M.C., Atanda, O.O., Ezekiel, C.N., Dipeolu, A.O., Uzochukwu, S.V.A., Oyedepo, J. and Chilaka, C.A. 2014. 'Distribution of mycotoxins and risk assessment of maize consumers in five agro-ecological zones of Nigeria'. *European Food Research and Technology* 239 (2): 287–296.

Adoga, G.I. and Obatomi, D.K. 1992. 'Preparatory methods of some Nigerian crops and foods that predispose to mycotoxin contamination'. Proceedings of the *First National Workshop on Mycotoxins*, 29 November 1990, Jos, Nigeria.

AECOM International Development. 2011. *Technical Report: Regulatory Environment for Animal Feeds in Zambia, Malawi, Mozambique, Zimbabwe, Namibia and Botswana*. Whitehouse & Associates, Gaborone, Botswana.

Agag, B.I. 2004. 'Mycotoxins in foods and feeds: 1-aflatoxins'. *Assiut University Bulletin Environmental Researches* 7 (1): 173–205.

Ahmed, A., Abass, S.E. and Ahmed Elbashir, A. 2016. 'Determination of aflatoxins in groundnut and groundnut products in Sudan using AflaTest® and HPLC'. *Memorias del Instituto de Investigaciones en Ciencias de la Salud 14*(2): 35–39.

Aizhen, L., Boris, E., Bravo-Ureta, B.E., Okello, D.K., Deom, C.M. and Puppala, N. 2013. *Groundnut Production and Climatic Variability: Evidence from Uganda*. Zwick Center for

Food and Resource Policy Working Papers Series No. 17. University of Connecticut, Connecticut, USA.

Ajeigbe, H.A., Waliyar, F., Echekwu, C.A., Ayuba, K., Motagi, B.N., Eniayeju, D. and Inuwa, A. 2014. *A Farmer's Guide to Groundnut Production in Nigeria*. International Crops Research Institute for the Semi-Arid Tropics, Telangana, India.

Akano, D. and Atanda, O. 1990. 'The present level of aflatoxin in Nigerian groundnut cake *('Kulikuli'*)'. *Letters in Applied Microbiology* 10: 187–189

Akinyele, I. 2008. *Ensuring Food and Nutrition Security in Rural Nigeria: An Assessment of the Challenges, Information Needs, and Analytical Capacity*. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/sites/default/files/publications/nsspbp07.pdf [Accessed 5 April 2012].

Akobundu, E. 1998. Farm-Household Analysis of Policies Affecting Groundnut Production in Senegal. MSc Thesis. Virginia Polytechnic Institute and State University, Virginia, USA.

Alemu, B. and Abera, D. 2014. 'Adaptation study of improved groundnut (*Arachis hypogaea* L) varieties at Kellem Wollega zone, Haro Sabu, Ethiopia'. *Journal of Biology, Agriculture and Healthcare* 4 (23): 75–79.

Ali, M.A., El Zubeir, I. and Fadel Elseed, A.M. 2014. 'Aflatoxin M_1 in raw and imported powdered milk sold in Khartoum state, Sudan'. *Food Additives & Contaminants: Part B* 7 (3): 208–212.

Aliabadi, M.A., Alikhani, F.E., Mohammadi, M. and Darsanaki, R.K. 2013. 'Biological control of aflatoxins'. *European Journal of Experimental Biology* 3(2): 162–166.

Alla, A.E.S.A., Neamat-Allah, A.A. and Aly, S.E. 2000. 'Situation of mycotoxins in milk, dairy products and human milk in Egypt'. *Mycotoxin Research* 16 (2): 91–100.

Allen, S.J., Wild, C.P., Wheeler, J.G., Riley, E.M., Montesano, R., Bennett, S. and Greenwood, B.M. 1992. 'Aflatoxin exposure, malaria and hepatitis B infection in rural Gambian children'. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 86 (4): 426–430.

Alliance for a Green Revolution in Africa (AGRA). 2013. *Establishing the Status of Post-harvest Losses and Storage for Major Staple Crops in Eleven African Countries (Phase I)*. AGRA, Nairobi, Kenya

Alpert, M.E., Hutt, M.S.R. and Davidson, C.S. 1968. 'Hepatoma in Uganda: A study in geographic pathology'. *The Lancet* 291 (7555): 1265–1267.

Alpert, M.E., Hutt, M.S.R., Wogan, G.N. and Davidson, C.S. 1971. 'Association between aflatoxin content of food and hepatoma frequency in Uganda'. *Cancer* 28 (1): 253–260.

Amani, H.K.R. 2004. *Agricultural Development and Food Security in Sub-Saharan Africa: Tanzania Country Report*. Economic and Social Research Foundation (ESRF), Dar es Salaam, Tanzania.

Amare, A., Dawit, A. and Mengistu, H. 1995. 'Micoflora, aflatoxin resistance of groundnut cultivars from eastern Ethiopia'. *Ethiopian Journal of Science* 18: 17–130.

Amer, A.A. and Ibrahim, M.E. 2010. 'Determination of aflatoxin M1 in raw milk and traditional cheeses retailed in Egyptian markets'. *Journal of Toxicology and Environmental Health Sciences* 2 (4): 50–3.

Amoa-Awua, W.K., Ngunjiri, P., Anlobe, J., Kpodo, K., Halm, M., Hayford, A. and Jakobsen, M. 2007. 'The effect of applying GMP and HACCP to traditional food processing at a semi-commercial kenkey production plant in Ghana'. *Food Control* 18 (11): 1449–1457.

Anon. 2001. 'Grain quality of the 1999/2000 South African Maize Crop'. Southern African Grain Laboratory, Pretoria, South Africa.

Arnot, L.F., Duncan, N.M., Coetzer, H. and Botha, C.J. 2012. 'An outbreak of canine aflatoxicosis in Gauteng Province, South Africa'. *Journal of the South African Veterinary Association* 83 (1): 01–04.

Ashworth, L J. and Langley, B.C. 1964. 'The relationship of pod damage to kernel damage by molds in Spanish peanuts'. *Plant Disease Reporter* 48: 875–878.

Asiki, G., Seeley J., Srey, C., Baisley, K., Lightfoot, T., Archileo, K. and Gong, Y.Y. 2014. 'A pilot study to evaluate aflatoxin exposure in a rural Ugandan population'. *Tropical Medicine & International Health* 19 (5): 592–599.

Assefa, D., Teare, M. and Skinnes, H. 2012. 'Natural occurrence of toxigenic fungi species and aflatoxin in freshly harvested groundnut kernels in Tigray, Northern Ethiopia'. *Journal of the Drylands* 5 (1): 377–384.

Atanda, O.O., Oguntubo, A., Adejumo, A., Ikeorah, H. and Akpan, I. 2007. 'Aflatoxin M_1 contamination of milk and ice-cream in Abeokuta and Odeda local governments of Ogun State, Nigeria'. *Chemosphere* 68: 1455–1458.

Atehnkeng, J., Ojiambo, P.S., Donner, M., Ikotun, T., Sikora, R.A., Cotty, P.J. and Bandyopadhyay, R. 2008. 'Distribution and toxigenicity of *Aspergillus* species isolated from maize kernels from three agro-ecological zones in Nigeria'. *International Journal of Food Microbiology* 122 **(**1): 74–84.

Australian Centre for International Agricultural Research (ACIAR). 2015. Cultivate Africa's Future (CultiAF). [Online]. *ACIAR*. Available at: http://aciar.gov.au/aifsc/cultivating-africas-future-cultiaf

Autrup, H., Seremet, T., Wakhisi, J. and Wasunna, A. 1987. 'Aflatoxin exposure measured by urinary excretion of aflatoxin B_1-guanine adduct and hepatitis B virus infection in areas with different liver cancer incidence in Kenya'. *Cancer Research* 47 (13): 3430–3433. Available at: http://www.afro.who.int/csr/ids/bulletins/eastern/jun2004.pdf [Accessed 15 January 2016].

Avantaggiato, G., Quaranta, F., Desiderio, E., Visconti, A. 2003. 'Fumonisin contamination of maize hybrids visibly damaged by *Sesamia*'. *Journal of the Science of Food and Agriculture* 83 (1): 13–18.

Awuah, E. 2000. 'Assessment of risk associated with consumption of aflatoxin-contaminated groundnut in Ghana'. *In* Awuah, R.T. and Ellis, W.O. *Proceedings of the National Workshop on Groundnut and Groundnut Aflatoxins.* UGC Publishing House, Kumasi, Ghana.

Awuah, R.T. and Ellis, W.O. 2002. 'Effects of some groundnut packaging methods and protection with *Ocimum* and *Syzygium* powders on kernel infection by fungi'. *Mycopathologia* 154: 29–26.

Awuah, R.T. and Kpodo, K.A. 1996. 'High incidence of *Aspergillus flavus* and aflatoxins in stored groundnut in Ghana and the use of a microbial assay to assess the inhibitory effects of plant extracts on aflatoxin synthesis'. *Mycopathologia 134* (2): 109–114.

Awuor, A.O., Montgomery, J., Yard, E., Martin, C., Daniel, J., Zitomer, N., Rybak, M., Lewis, L., Phillips, T., Romoser, A. and Elmore, S. 2016. 'Evaluation of efficacy, acceptability and palatability of calcium montmorillonite clay used to reduce aflatoxin B1 dietary exposure in a crossover study in Kenya'. *Food Additives & Contaminants: Part A* (published online ahead of print edition).

Ayalew, A. 2010. 'Mycotoxins and surface and internal fungi of maize from Ethiopia'. *African Journal of Food, Agriculture, Nutrition and Development* 10 (9): 4109-4123.

Ayalew, A., Chunga, W. and Sintayehu, W. 2013. 'Mobilizing political support: Partnership for aflatoxin control in Africa'. *In* Unnevehr, L. and Grace, D. (eds.) *Aflatoxins: Finding Solutions for Improved Food Safety*. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/publication/aflatoxins-finding-solutions-improved-food-safety

Ayalew, A., Fehrmann, H., Lepschy, J., Beck, R. and Abate, D. 2006. 'Natural occurrence of mycotoxins in staple cereals from Ethiopia'. *Mycopathologia* 162 (1): 57–63.

Azziz-Baumgartner, E., Lindblade, K., Gieseker, K., Rogers, H.S., Kieszak, S. and Njapau, H. 2005. 'Case-control study of an acute aflatoxicosis outbreak, Kenya, 2004'. *Environmental Health Perspectives* 113 (12): 1779–1783.

Babana, A.H., Keita, C., Traoré, D., Samaké, F., Dicko, A.H., Faradji, F.A., Maïga, K. and Diallo, A, 2013. 'Evaluation of the sanitary quality of peanut butters from Mali: Identification and quantification of aflatoxins and pathogens'. *Scientific Journal of Microbiology* 2 (8): 150–7.

Bakhiet, A.E.A. and Musa, A.A.A. 2011. 'Survey and Determination of Aflatoxin Levels in Stored Peanut in Sudan'. *Jordan Journal of Biological Sciences* 4 (1): 13–20.

Bandyopadhyay, R. and Cotty, P.J. 2013. 'Biological Controls or Aflatoxin Reduction'. *In* Unnevehr, L. and Grace, D. (eds.) *Aflatoxins: Finding Solutions for Improved Food Safety*. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/publication/aflatoxins-finding-solutions-improved-food-safety

Bandyopadhyay, R., Kumar, M. and Leslie, J.F. 2007. 'Relative severity of aflatoxin contamination of cereal crops in West Africa'. *Food Additives and Contaminants* 24 (10): 1109–1114.

Bankole, S.A. 1997. 'Effect of essential oil from two Nigerian medicinal plants (*Azadirachta indica* and *Morinda lucida*) on growth and aflatoxin B_1 production in maize grain by a toxigenic *Aspergillus flavus*'. *Letters in Applied Microbiology* 24: 190–192.

Bankole, S.A. and Adebanjo, A. 2003. 'Mycotoxins in food in West Africa: Current situation and possibilities of controlling it'. *African Journal of Biotechnology* 2: 254–263.

Bankole, S.A. and Kpodo, K.A. 2005. 'Mycotoxin contamination in food systems in West and Central Africa'. In *Reducing Impact of Mycotoxins in Tropical Agriculture, with Emphasis on Health and Trade in Africa*. Proceedings of the *Myco-Globe Conference*, 13–16 September 2005, Accra, Ghana.

Bankole, S.A. and Mabekoje, O.O. 2004. 'Occurrence of aflatoxins and fumonisins in preharvest maize from south-western Nigeria'. *Food Additives and Contaminants* 21 (3): 251–255.

Bankole, S.A., Schollenberger, M. and Drochner, W. 2006. 'Mycotoxin contamination in food systems in sub-Saharan Africa: A review'. *Mycotoxin Research* 22: 163–169.

Baquião, A.C., de Oliveira, M.M., Reis, T.A., Zorzete, P., Diniz, A.D. and Correa B. 2013. 'Polyphasic approach to the identification of *Aspergillus* section *Flavi* isolated from Brazil nuts'. *Food Chemistry* 139: 1127–1132.

Baranyi, N., Kocsube, S., Vagvolgyi, C. and Varga, J. 2013. 'Current trends in Aflatoxin research'. *Acta Biologica Szegediensis* 57: 95–107.

Barba, R. and Degbelo, J. 2006. *East African Community Trade Policy Review*. World Trade Organization (WTO), Geneva, Switzerland.

Barreiro-Hurle, J. 2012. *Analysis of Incentives and Disincentives for Maize in the United Republic of Tanzania*. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Barro, N., Ouattara, C.A., Nikiema, P.A., Ouattara, A.S. and Traoré, A.S. 2002. 'Microbial quality assessment of some street food widely consumed in Ouagadougou, Burkina Faso'. *Sante* 12 (4): 369–374.

Barry, D., Lillehoj, E.B., Wilsdrom, N.W., McMillan, N.W., Zuber, M.S., Kwolek, W.F. and Guthrie, W.D. 1986. Effect of husk tightness and insect (Lepidoptera) infestation on aflatoxin contamination of pre-harvest maize. Journal of Environmental Entomology 15: 1116–1118.

Bassa, S., Mestres, C., Champiat, D., Hell, K., Vernier, P. and Cardwell, K. 2001. 'First report of aflatoxin in dried yam chips in Benin'. *Plant Disease* 85 (9): 1032–1032.

Bassir, O. 1969. 'Toxic substance in foodstuffs'. *West African Journal of Biological and Applied Chemistry* 12: 4–7.

Bassir, O. and Adekunle, A. 1969. 'Comparative toxicities of Aflatoxin B_1 and palmotoxins B_o and G_o'. *West African Journal of Biological and Applied Chemistry* 12 (1): 7–19.

Bastianello, S.S., Nesbit, J.W., Williams, M.C. and Lange, A.L.1987. 'Pathological findings in a natural outbreak of aflatoxicosis in dogs'. *Onderstepoort Journal of Veterinary Research* 54: 635–640.

Bates, R.H. 1989. *Markets and States in Tropical Africa*. University of California Press, Berkeley, USA.

Bayman, P. and Cotty, P.J. 1991. 'Vegetative compatibility and genetic diversity in the *Aspergillus flavus* population of a single field'. *Canadian Journal of Botany* 69: 1707–1711.

Bayman, P. and Cotty, P.J. 1993. 'Genetic diversity in *Aspergillus flavus* - Association with aflatoxin production and morphology'. *Canadian Journal of Botany* 71: 23–31.

Bbosa, G.S., Kitya, D., Lubega, A., Ogwal-Okeng, J., Anokbonggo, W.W. and Kyegombe, D.B. 2013. 'Review of the biological and health effects of aflatoxins on body organs and body systems: Aflatoxins—Recent advances and future prospects'. *Intechopen Publisher* 12: 239–265.

Beghin, J.C. 1991. 'Estimation of price policies in Senegal: An empirical test of cooperative game theory'. *Journal of Development Economics* 35: 49–67.

Benkerroum, N. 2013. 'Traditional fermented foods of North African countries: Technology and food safety challenges with regard to microbiological risks'. *Comprehensive Reviews in Food Science and Food Safety* 12(1): 54–89.

Bennett, J.W. and Klich, M.A. 2003. 'Mycotoxins'. *Clinical Microbiology Reviews* 16 (3): 497–516.

Berthiller, F., Burdaspal, P., Crews, C., Iha, M., Krska, R. and Lattanzio, V. 2014. 'Developments in mycotoxin analysis: An update for 2012–2013'. *World Mycotoxin Journal* 7 (1): 3–33.

Bhat, R.V. 1991. 'Aflatoxins: successes and failures of three decades of research'. *In* Champ, B.R., Highley, E., Hocking, A.D. and Pitt, J.I (eds.) *Fungi and Mycotoxins in Stored Products: Proceedings of an International Conference, Bangkok, Thailand, 23–26 April 1991*. Australian Centre for International Agricultural Research, Canberra, Australia.

Bhat, R.V. and Vashanti, S. 1999. 'Occurrence of aflatoxins and its economic impact on human nutrition and animal feed'. *The New Regulation Agric. Development* 23: 50–56.

Bhatnagar-Mathur, P., Sunkara, S., Bhatnagar-Panwar, M., Waliyar, F. and Sharma, K.K. 2015. 'Biotechnological advances for combating *Aspergillus flavus* and aflatoxin contamination in crops'. *Plant Science* 234: 119–132.

Bickford, R. and Mabiletsa, P. 2006. *South Africa, Republic of Food and Agricultural Import Regulations and Standards Country Report*. GAIN Report Number: SF6027. United States Department of Agriculture Foreign Agricultural Service, Washington, DC, USA.

Bilgrami, K.S., Sinha, S.P. and Jeswal, P. 1988. 'Loss of toxigenicity of *Aspergillus flavus* strains during subculturing: A genetic interpretation'. *Current Science* 57, 551–552.

Bintavihok, A., Taveetiyanont, D., Kositcharoenkul, S., Panichkriangkrai, V. and Chamruschay, O. 1997. 'The detection of aflatoxin and its metabolite in poultry tissue in Bangkok'. *Chula Research* 16: 10–7.

Bisrat, A. and Gebre, P. 1981. 'A preliminary study on the aflatoxin content of selected Ethiopian food. *Ethiopia Medical Journal* 19: 47–52.

Blackie, M.J. 1990. 'Maize, food self-sufficiency and policy in east and southern Africa'. *Food Policy* 15: 838–394.

Blount, W.P. 1961. 'Turkey "X" disease'. *Turkeys* 9 (2): 52–55.

Boakye-Yiadom. 2003. *An Economic Surplus Evaluation of Aflatoxin-reducing Research: A Case Study of Senegal's Confectionery Groundnut Sector*. Thesis submitted to the Faculty of Virginia Polytechnic Institute and State University, Virginia, USA.

Bonaventure, S., Guillot, S., Fatajo, F.S., Cham, E. and Bemba, S.M. 2010. *Pre-Harvest Assessment of the 2010/2011 Cropping Season: Food and Nutrition Outlook, and the Ex-*

post and Provisional Cereal and Food Balance Sheet. Republic of The Gambia, Banjul, The Gambia.

Boonyaratanakornkit, M. and Chinbuti, A. 2004. 'Situation of aflatoxin contamination in groundnut products in Thailand in 2004'. Proceedings of the *43rd Kasetsart University Annual Conference*, 1–4 February 2005, Thailand.

Bouraima, Y., Ayi-Fianou, L., Kora, I., Sanni, A. and Creppy, E.E. 1993. 'Mise en evidencede la contamination des cereals par les aflatoxines et l'ochratoxine A au Benin'. *In* Creppy, E.E., Castegnaro, M. and Dirheimer, G. (eds.) *Human Ochratoxicosis and its Pathologies*. John Libbey Eurotext, Montrouge, France.

Brown, R.L., Bhatnagar, D., Cleveland, T.E., Chen, Z. and Menkir, A. 2013. 'Development of maize host resistance to aflatoxigenic fungi'. *In* Mehdi, M.R. (eds.) *Aflatoxins: Recent Advances and Future Prospects*. InTech, Rijeka, Croatia.

Brown, R.L., Chen, Z.Y., Menkir, A., Cleveland, T.E., Cardwell, K., Kling, J. and White, D.G. 2001. 'Resistance to aflatoxin accumulation in kernels of maize inbreds selected for ear rot resistance in West and Central Africa'. *Journal of Food Protection* 64 (3): 396–400.

Bruns, H.A. 2003. 'Controlling aflatoxin and fumonisin in maize by crop management'. *Journal of Toxicology* 22: 153–173.

Buchanan-Smith, M., and Fadul, A.A. 2008. *Adaptation and Devastation: The Impact of Conflict on Trade and Markets in Darfur. Findings of a Scoping Study*. Feinstein International Center, Tufts University, Medford, USA.

Buchanan-Smith, M., Fadul, A., Tahir, A.R., Ismail, M.A., Ahmed, N.I., Adam, M.I.G., Kaja, Z.Y., Eissa, A.M.A., Mohamed, M.A.M. and Jumma, A.H.H.M. 2013. *Taking Root: The Cash Crop Trade in Darfur*. Feinstein International Center, Tufts University and United Nations Environment Programme (UNEP), Sudan. Available at: http://fic.tufts.edu/publication-item/taking-root/

Buchanan Smith, M., and Jaspars, S. 2006. *Conflict, Camps and Coercion: The Continuing Livelihoods Crisis in Darfur*. World Food Programme (WFP), Khartoum, Sudan.

Buguzi, S. 2016. 'Tanzania: Food poisoning linked to 14 deaths in two regions. *The Citizen* [online], 20 July 2016. Available at: http://allafrica.com/stories/201607290685.html [Accessed 18 September 2016].

Bumbangi, N.F., Muma, J.B., Choongo, K., Mukanga, M., Velu, M.R., Veldam, F., Hatloy, A. and Mapatano, M.A. 2016. 'Occurrence and factors associated with aflatoxin contamination of raw peanuts from Lusaka district's markets, Zambia'. *Food Control* 68: 291–296.

Bureau for Agriculture Consultancy and Advisory Service (BACAS). 2000. *Final Report: Baseline Survey on the Agricultural Research System Under the Department of Research and Training. Volume 1 - Western Zone. Synthesis of Main Findings and Recommendations*. Sokoine University of Agriculture Morogoro, Tanzania.

Bureau for Food and Agricultural Policy (BFAP). 2012. *Evaluating the Sustainability of the South African Groundnut Industry*. BFAP, Pretoria, South Africa. Available at: http://www.bfap.co.za/documents/research%20reports/Evaluating%20the%20sustainability%20of%20the%20South%20African%20Groundnut%20industry%20(2011).pdf

Byanyima, M. 2012a. *COMESA Mission Report, Strategy/Planning Meeting Towards Harmonization of Biopesticides Regulatory Framework in Africa, 12–13 June 2012, Zanzibar, Tanzania*. COMESA, Lusaka, Zambia.

Byanyima, M. 2012b. *COMESA Report on Regional Training on Harmonizing Sampling and Testing Procedures of Aflatoxin Control, 28–29 February 2012, Nairobi, Kenya*. Common Market for Eastern and Southern Africa (COMESA), Lusaka, Zambia.

Byanyima, M. (eds.). 2013. *Establishing Priorities for SPS Capacity-Building in Uganda Using Multi Criteria Decision Analysis*. Common Market for Eastern and Southern Africa (COMESA), Lusaka, Zambia.

Byaruhanga, P. 2012. *Sihubira Multipurpose Cooperative Society (SIMUCO) Scope of Work*. Cultivating New Frontiers in Agriculture (CNFA), Uganda.

Cadoni, P. and Angelucci, F. 2013. *Analysis of Incentives and disincentives for Maize in Nigeria*. Technical Notes Series. Monitoring and Analysing Food and Agricultural Policies (MAFAP) programme of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Caliskan, S., Caliskan, M.E., Arslan, M. and Arioglu, H. 2008. 'Effects of sowing date and growth duration on growth and yield of groundnut in a Mediterranean type environment in Turkey'. *Field Crops Research* 105 (1–2): 131–140.

Calderari, T.O., Iamanaka, B.T., Frisvad, J.C., Pitt, J.I., Sartori, D., Pereira, J.L. and Taniwaki, M.H. 2013. 'The biodiversity of *Aspergillus* section Flavi in Brazil nuts: From rainforest to consumer'. *International Journal of Food Microbiology* 160 (3): 267–272.

Carnaghan, R.B.A. 1965. 'Hepatic tumours in ducks fed a low level of toxic groundnuts meal'. *Nature* 208: 308.

Castelino, J.M., Routledge, M.N., Wilson, S., Dunne, D.W., Mwatha, J.K., Gachuhi, K., Wild, C.P. and Gong, Y.Y., 2015. 'Aflatoxin exposure is inversely associated with IGF1 and IGFBP3 levels in vitro and in Kenyan schoolchildren'. *Molecular Nutrition and Food Research* 59(3): 574–581.

Caswell, N. 1985. 'Peasants, peanuts and politics: State marketing in Senegal 1966–80'. *In* Kwame, A., Hesp, P. and van der Laan, L. (eds.) *Marketing Boards in Tropical Africa*. KPI Limited, London, UK.

Center for Disease Control and Prevention (CDC). 2004a. 'Outbreak of aflatoxin poisoning – eastern and central provinces, Kenya, January–July 2004'. *Morbidity and Mortality Weekly Report* 53 (34): 790.

Center for Disease Control and Prevention (CDC). 2004b. 'Outbreak of aflatoxin poisoning in Kenya'. *Morbidity and Mortality Weekly Report* 53(34): 790–793. Available at: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5334a4.htm [Accessed 1 October 2016].

CGIAR. 2010. Malawi Seed Industry Development [online]. Available at: http://ongoing-research.cgiar.org/factsheets/malawi-seed-industry-development.

CGIAR Research Programme on Grain Legumes. 2012. Leveraging Legumes to Combat Poverty, Hunger, Malnutrition and Environmental Degradation. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Center for Tropical

Agriculture (CIAT), International Center for Agricultural Research in the Dry Areas (ICARDA) and International Institute of Tropical Agriculture (IITA).

Chala, A., Mohammed, A., Ayalew, A. and Skinnes, H. 2013. 'Natural occurrence of aflatoxins in groundnut (*Arachis hypogaea* L.) from eastern Ethiopia'. *Food Control* 30 (2): 602–5.

Chala, A., Abate, B., Taye, M., Mohammed, A., Alemu, T. and Skinnes. H. 2014a. *Opportunities and Constraints of Groundnut Production in Selected Drylands of Ethiopia.* Drylands Coordination Group, Oslo, Norway.

Chala, A., Taye, W., Ayalew, A., Krska, R., Sulyok, M. and Logrieco, A. 2014b. 'Multimycotoxin analysis of sorghum (*Sorghum bicolor* L. Moench) and finger millet (*Eleusine coracana* L. Garten) from Ethiopia. *Food Control* 45: 29–35.

Chang, P.K., Horn, B.W. and Dorner, J.W. 2005. 'Sequence breakpoints in the aflatoxin biosynthesis gene cluster and flanking regions in nonaflatoxigenic *Aspergillus flavus* isolates'. *Fungal Genetetics and Biology* 42: 914–923.

Chao, T.C., Maxwell, S.M. and Wong, S.Y. 1991. 'An outbreak of aflatoxicosis and boric acid poisoning in Malaysia: A clinicopathological study'. *The Journal of Pathology* 164 (3): 225–233.

Chapoto, A. and Jayne, T.S. 2011. *Zambian Farmers' Access to Maize Markets*. Food Security Research Project (FSRP) Working Paper No. 57. FSRP, Lusaka, Zambia.

Chauliac, M., Bricas, N., Ategbo, E., Amoussa, W. and Zohoun, I. 1998. 'Food habits outside the home by school children in Cotonou, Benin'. *Sante* 8 (2): 101–108.

Chauvin, N.D., Mulangu, F. and Porto, G. 2012. *Food Production and Consumption Trends in Sub-Saharan Africa: Prospects for the Transformation of the Agricultural Sector*. United Nations Development Programme, Regional Bureau for Africa, New York, USA.

Cheli, F., Campagnoli, A., Pinotti, L. and Dell'Orto, V. 2012. 'Rapid methods as analytical tools for food and feed contaminant evaluation: Methodological implications for mycotoxin analysis in cereals'. *In* Aladjadjiyan, A. (ed.) *Food Production: Approaches, Challenges and Tasks*. InTech, Rijeka, Croatia. Available at: http://cdn.intechweb.org/pdfs/26523.pdf [Accessed 22 October 2016].

Chelule, P.K., Gqaleni, N., Dutton, M.F. and Chuturgoon, A.A. 2001. 'Exposure of rural and urban populations in KwaZulu Natal, South Africa, to fumonisin B (1) in maize'. *Environmental Health Perspectives* 109 (3): 253.

Chelule, P.K., Mokoena, M.P. and Gqaleni, N. 2010. 'Advantages of traditional lactic acid bacteria fermentation of food in Africa'. *Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology* 2: 1160–1167.

Chen, Z.Y., Robert, L.B. and Thomas, E.C. 2004. 'Evidence for an association in corn between stress tolerance and resistance to *Aspergillus flavus* infection and aflatoxin contamination'. *African Journal of Biotechnology* 3 (12): 693–699.

Chiona, M., Ntawuruhunga, P., Benesi, I.R.M., Matumba, L. and Moyo, C.C. 2014. 'Aflatoxins contamination in processed cassava in Malawi and Zambia'. *African Journal of Food, Agriculture, Nutrition and Development* 14: 8809–8820.

Codex Alimentarius Commission (CAC). 2000. *Harmonization and Cooperation in Food Legislation and Food Control Activities in the Region. Report of the Fourteenth Session of*

the Joint FAO/WHO Codex Alimentarius Commission Coordinating Committee for Africa. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Codex Alimentarius Commission (CAC). 2005. *Comments from Uganda: Joint FAO/WHO Food Standards Programme, FAO/WHO Coordinating Committee for Africa Sixteenth Session*. CAC, Rome, Italy.

Codex Alimentarius Commission (CAC). 2008. *Report of the 61st Session of the Executive Committee of the Codex Alimentarius Commission*. CAC, Rome, Italy.

Codex Alimentarius Commission (CAC). 2009. *Joint FAO/WHO Food Standards Programme*. Nineteenth Edition. CAC, Rome, Italy.

Cole, R.J. and Cox, R.H. 1981. *Handbook of Toxic Fungal Metabolites*. Academic Press, New York, USA.

Cole, R.J., Sanders, T.H., Hill, R.A. and Blankenship, P.D. 1985. 'Mean geocarposphere temperature that induce preharvest aflatoxin contamination of peanut under drought stress'. *Mycopathologia* 91: 41.

Cole, R.J., Schweikert, M.A. and Jarvis, B.B. 2003. *Handbook of Secondary Fungal Metabolites*. Vol. 1–3. Academic Press, New York, USA.

Cole, R.J., Sobolev, V.S. and Dorner, J.W. 1993. 'Potentially important sources of resistance to prevention of preharvest aflatoxin contamination in peanuts'. *In* Sholar, J.R. (ed.) *Proceedings of the American Peanut Research and Education Society (APRES). Vol. 25.* APRES, Tifton, Georgia.

Common Market for Eastern and Southern Africa (COMESA). 2009. *Staple Food Trade in the COMESA Region: The Need for a Regional Approach to Stimulate Agricultural Growth and Enhance Food Security*. Twenty-Fourth Meeting of the Trade and Customs Committee, Nairobi, Kenya.

Common Market for Eastern and Southern Africa (COMESA). 2014. *Regional Workshop Report on the Aflatoxin Challenge in Eastern and Southern Africa. Theme: Improving Health, Trade and Food Security through Regional Efforts to Mitigate Aflatoxin Contamination 11–13 March 2014*. COMESA, Lusaka, Zambia Available at: http://www.aflatoxinpartnership.org/uploads/COMESA%20AFLATOXIN%20WORKSHOP%20FINAL%20REPORT.pdf

Community Markets for Conservation (COMACO). 2013. *COMACO Strategic Plan 2014–2018*. COMACO, Lusaka, Zambia.

Constant, J.L., Kocheleff, P., Carteron, B., Perrin, J., Bedere, C. and Kabondo, P. 1984. 'Geographical distribution of aflatoxins in human food in Burundi [hepatoma, altitude]'. *Sciences des Aliments* 4 (2): 305–315.

Cotty, P.J. 1989. 'Virulence and cultural characteristics of two *Aspergillus flavus* strains pathogenic on cotton'. *Phytopathology* 79: 808–814.

Cotty, P.J. 1990. 'Effect of atoxigenic strains of *Aspergillus flavus* on aflatoxin contamination of developing cottonseed'. *Plant Disease* 74**:** 233–235.

Cotty, P.J. 1997. 'Aflatoxin-producing potential of communities of *Aspergillus* section Flavi from cotton producing areas in the United States'. *Mycological Resea*rch 101: 698–704.

Cotty, P.J. and Cardwell, K.F. 1999. 'Divergence of West African and North American communities of *Aspergillus* section Flavi'. *Applied and Environmental Microbiology* 65: 2264–2266.

Coulter, J.B., Suliman, G.I., Lamplugh, S.M., Mukhtar, B.I. and Hendrickse, R.G. 1986. Aflatoxins in liver biopsies from Sudanese children. *The American Journal of Tropical Medicine and Hygiene* 35: 360–5.

Council for Agriculture, Science and Technology (CAST), 2003): *Mycotoxins: Risks in Plant, Animal and Human Systems*. CAST, Ames, Iowa, USA.

Craufurd, P.Q., Prasad, P.V.V., Waliyar, F. and Taheri, A. 2006. 'Drought, pod yield, preharvest Aspergillus contamination on peanut in Niger'. *Field Crops Research* 98: 20–29.

Central Statistical Agency of Ethiopia (CSA). 2003. *Statistical Report on Area and Production. Country Forecast of Major Crops: Agricultural Sample Enumeration Surveys, Various Issues*. CSA, Addis Ababa, Ethiopia

Central Statistical Agency of Ethiopia (CSA). 2005. *Statistical Report on Area and Production. Country Forecast of Major Crops: Agricultural Sample Enumeration Surveys, Various Issues*. CSA, Addis Ababa, Ethiopia.

Central Statistical Agency of Ethiopia (CSA). 2011. *Agricultural Sample Survey for the 2010/2011 Crop Season. Volume I. Report on Area and Production of Crops for Private Peasant Holdings (Meher Season)*. Statistical Bulletin. CSA, Addis Ababa, Ethiopia.

Dada, J.D. 1978. *Studies of Fungi Causing Grain Mould of Sorghum Varieties in Northern Nigeria with Special Emphasis on Species Capable of Producing Mycotoxins*. M.Sc. Thesis. Ahmadu Bello University, Zaria, Nigeria.

Dalezios, J., Wogan, G.N. and Weinreb, S.M. 1971. 'Aflatoxin P-1: A new aflatoxin metabolite in monkeys'. *Science* 171: 584–585.

Daniel, J.H., Lewis, L.W., Redwood, Y.A., Kieszak, S., Breiman, R.F., Flanders, W.D. and McGeehin, M.A. 2011. 'Comprehensive assessment of maize aflatoxin levels in eastern Kenya'. *Environmental Health Perspectives* 119 (12): 1795.

Daramola, A.M. 1986. 'Corn earworm infestation of seven maize cultivars and control in south-western Nigeria'. *International Journal of Tropical Insect Science* 7 (01): 49–52.

Darling, S.J. 1963. *Research on Aflatoxin in Groundnuts in Nigeria*. Institute of Agricultural Research, Ahmadu Bello University, Samaru, Zaria, Nigeria.

Davis, N.D., Dickens, J.W., Freie, R.L., Hamilton, P.B., Shotwell, O.L., Wyllie, T.D. and Fulkerson, J.F. 1980. 'Protocols for survey, sampling, post-collection handling, and analysis of grain samples involved in mycotoxin problems'. *Association of Official Analytical Chemists* 63 (1): 95–102.

De Vries, H.R., Lamplugh, S.M. and Hendrickse, R.G. 1986. 'Aflatoxins and kwashiorkor in Kenya: A hospital based study in a rural area of Kenya'. *Annals of Tropical Paediatrics* 7: 249–251.

De Vries, H.R., Maxwell, S.M. and Hendrickse, R.G. 1990. 'Aflatoxin excretion in children with kwashiorkor or marasmic kwashiorkor – a clinical investigation'. *Mycopathologia* 110: 1–9.

De Waal, A. 2005. *Famine That Kills: Darfur, Sudan*. Revised Edition. Oxford University Press, New York, USA.

Dereszynski, D.M., Center, S.A., Randolph, J.F., Brooks, M.B., Hadden, A.G., Palyada, K.S. and Sanders, S.Y. 2008. 'Clinical and clinicopathologic features of dogs that consumed foodborne hepatotoxic aflatoxins: 72 cases (2005–2006)'. *Journal of the American Veterinary Medical Association* 232 (9): 1329–1337.

Department of Agriculture, Forestry and Fisheries. 2010. *Groundnuts. Production Guidelines*. Directorate Marketing. Republic of South Africa, Pretoria, South Africa.

Department of Agriculture, Forestry and Fisheries. 2014. *Maize Market Value Chain Profile*. Directorate Marketing. Republic of South Africa, Pretoria, South Africa.

Department of Health and Human Services. 1991. *Sixth Annual Report On Carcinogens*. National Toxicology Program, US Department of Health and Human Services, Public Health Service, Research Triangle Park, NC, USA.

Department of Research and Information. 2014. *Trade Report. Export Opportunities for South Africa in Selected African Countries*. Industrial Development Corporation of South Africa, Gauteng, South Africa

Derlagen, C. and Phiri, H., 2012. *Analysis of Incentives and Disincentives for Groundnuts in Malawi*. Technical Notes Series. Monitoring and Analysing Food and Agricultural Policies (MAFAP) programme of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Diallo, M.S., Sylla, A., Sidibé, K., Sylla, B.S., Trepo, C.R. and Wild, C.P. 1995. 'Prevalence of exposure to aflatoxin and hepatitis B and C viruses in Guinea, West Africa'. *Natural Toxins* 3 (1): 6–9.

Díaz-Bonilla, E. and Reca, L. 2000. 'Trade and agroindustrialization in developing countries: Trends and policy impacts'. *Agricultural Economics* 23 (3): 219–29.

Diaz-Gomez, J., Marin, S., Capell, T., Sanchis, V. and Ramos, A.J. 2016. 'The impact of Bacillus thuringiensis technology on the occurrence of fumonisins and other mycotoxins in maize'. *World Mycotoxin Journal* 9(3): 475–486.

Diaz-Rios, J. 2008. *Standards, Competitiveness, and Africa's groundnut Exports to Europe: Barrier, Catalyst, or Distraction? Agriculture & Rural Development Department*. Discussion Paper 39. The International Bank for Reconstruction and Development/the World Bank, Washington, DC, USA.

Diedhiou, P.M., Bandyopadhyay, R., Atehnkeng, J. and Ojiambo, P.S. 2011. '*Aspergillus* colonization and aflatoxin contamination of maize and sesame kernels in two agro-ecological zones in Senegal'. *Journal of Phytopathology* 159 (4): 268–275.

Diener, U.L., Cole, R.J., Sanders, T.H., Payne, G.A., Lee, L.S. and Klich, M.A. 1987. 'Epidemiology of aflatoxin formation by *Aspergillus flavus*'. *Annual Review of Phytopathology* 25: 249–270.

Ding, X., Wu, L., Li, P., Zhang, Z., Zhou, H., Bai, Y., Chen, X. and Jiang, J. 2015. 'Risk assessment on dietary exposure to aflatoxin B_1 in post-harvest peanuts in the Yangtze River ecological region'. *Toxins* 7 (10): 4157–4174.

Diop, N., J.C. Beghin, and M. Sewadeh. 2004. *Groundnut Policies, Global Trade Dynamics, and the Impact of Trade Liberalization*. World Bank Policy Research Working Paper No. 3226. World Bank, Washington, DC, USA. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/14213/WPS3226.pdf;sequence=1

Diop, Y., Ndiaye, B., Diouf, A., Fall, M., Thiaw, C., Thiam, A. and Ba D. 2000. 'Artisanal peanut oil contaminated by aflatoxins in Senegal'. *Annales Pharmaceutiques Francaises* 58: 470–474.

Doss, C.R., Mwangi, W., Verkuijl, H. and Groote, H.D. 2003. *Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies*. International Maize and Wheat Improvement Center (CIMMYT) Economics Working Paper 03–06. CIMMYT, El Batán, Mexico.

Dowd, P.F. 2003. 'Insect management to facilitate preharvest mycotoxin management. *Journal of Toxicology* 22: 327–350.

Durufle, G. 1995. 'Bilande la nouvelle politique agricole au Senegal'. *Review of African Political Economy* 63: 73–84.

Dutton, M.F. and Kinsey, A. 1996. 'A note on the occurrence of mycotoxins in cereals and animal feedstuffs in Kwazulu Natal, South Africa 1984–1993'. *South African Journal of Animal Science* 26 (2): 53–57.

Dutton, M.F., Mwanza, M., de Kock, S. and Khilosia, L.D. 2012. 'Mycotoxins in South African foods: a case study on aflatoxin M_1 in milk'. *Mycotoxin Research* 28 (1): 17–23.

Eaton, D.L. and Heinonen, J.T. 1997. 'Aflatoxins'. *In* Sipes, I.G., McQueen, C.A., and Gandolfi, A.J. (eds.) Comprehensive Toxicology. Elsevier Sciences, Oxford, England.

Ediage, E.N., Hell, K. and De Saeger, S. 2014. 'A comprehensive study to explore differences in mycotoxin patterns from agro-ecological regions through maize, peanut, and cassava products: a case study, Cameroon'. *Journal of Agricultural and Food Chemistry* 62 (20): 4789–97.

Egel, D.S., Cotty, P.J. and Elias, S. 1994. 'Relationship among isolates of *Aspergillus* sect. *flavi* that vary in aflatoxin production'. *Phytopathology* 84: 906–912.

Egal, S., Hounsa, A., Gong, Y.Y., Turner, P.C., Wild, C.P., Hall, A.J. and Cardwell, K.F. 2005. 'Dietary exposure to aflatoxin from maize and groundnut in young children from Benin and Togo, West Africa'. *International Journal of Food Microbiology* 104 (2): 215–224.

Ehrlich, K.C. 2014. 'Non-aflatoxigenic *Aspergillus flavus* to prevent aflatoxin contamination in crops: Advantages and limitations'. *Frontiers in Microbiology* 10 (5): 50.

Ehrlich, K.C. and Cotty, P.J. 2004. 'An isolate of *Aspergillus flavus* used to reduce aflatoxin contamination in cottonseed has a defective polyketide synthase gene'. *Applied Microbiology and Biotechnology* 65: 473–478.

Ehrlich, K.C., Moore, G.G., Mellon, J.E. and Bhatnagar, D., 2014. 'Challenges facing the biological control strategy for eliminating aflatoxin contamination'. *World Mycotoxin Journal* 8(2): 225–233.

El-Gohary, A.H. 1996. 'Aflatoxicosis in some foodstuffs with special reference to public health hazard in Egypt'. *Indian Journal of Animal Sciences* 66 (5): 468–473.

El-Hassan, S.M., Naidu, R.A., Ahmed, A.H. and Murant, A.F. 1997. 'A serious disease of groundnut caused by cowpea mild mottle virus in the Sudan'. *Journal of Phytopathology* 145: 30–304.

El-Kady, I.A., El-Maraghy, S.S.M. and Mostafa, M.E. 1995. 'Natural occurrence of mycotoxins in different spices in Egypt'. *Folia Microbiologica* 40 (3): 297–300.

El-Tras, W.F., El-Kady, N.N. and Tayel, A.A. 2011. 'Infants exposure to Aflatoxin M_1 as a novel foodborne zoonosis'. *Food and Chemical Toxicology* 49 (11): 2816–2819.

Elgerbi, A.M., Aidoo, K.E., Candlish, A.A.G. and Tester, R.F. 2004. 'Occurrence of aflatoxin M_1 in randomly selected North African milk and cheese samples'. *Food Additives and Contaminants* 21 (6): 592–597.

El Mahgubi, A., Puel, O., Bailly, S., Tadrist, S., Querin, A., Ouadia, A., Oswald, I.P. and Bailly, J.D. 2013. 'Distribution and toxigenicity of *Aspergillus* section *Flavi* in spices marketed in Morocco'. *Food Control* 32: 143–148.

El Naim, A.M., Eldouma, M.A., Ibrahim, E.A., and Zaied, M.M.B. 2011. 'Influence of plant spacing and weeds on growth and yield of peanut (*Arachis hypogaea* L) in rain-fed of Sudan'. *Advances in Life Sciences* 1(2): 45–48.

Elshafie, S.Z., ElMubarak, A., El-Nagerabi, S.A. and Elshafie, A.E. 2011. 'Aflatoxin B_1 contamination of traditionally processed peanuts butter for human consumption in Sudan'. *Mycopathologia* 171 (6): 435–439.

El Tom, O.A., and Yagoub, A.E.A. 2007. 'Physicochemical properties of processed peanut (*Arachis hypogaea L.*) oil in relation to Sudanese standards: A case study in Nyala; South Darfur State; Sudan'. *Journal of Food Technology* 5 (1): 71–76.

Elzupir, A.O. and Elhussein, A.M. 2010. 'Determination of aflatoxin M_1 in dairy cattle milk in Khartoum State, Sudan'. *Food Control* 21 (6): 945–946.

Elzupir, A.O., Fadul, M.H., Modwi, A.K., Ali, N.M., Jadian, A.F., Ahmed, N.A., Adam, S.Y., Ahmed, N.A., Khairy, A.A. and Khalil, E.A. 2012. 'Aflatoxin M_1 in breast milk of nursing Sudanese mothers. *Mycotoxin Research* 28 (2): 131–4.

Elzupir, A.O., Suliman, M.A., Ibrahim, I.A., Fadul, M.H. and Elhussein, A.M. 2010. 'Aflatoxins levels in vegetable oils in Khartoum State, Sudan'. *Mycotoxin Research* 26 (2): 69–73.

Emmott, A. 2013. *Aflatoxins: Finding Solutions for Improved Food Safety. Market-Led Aflatoxin Interventions: Smallholder Groundnut Value Chains In Malawi*. International Food Policy Research Institute (IFPRI), Washington, DC, USA.

Emmott, A., and Stephens, A. 2012. *Scoping Economically Viable Mechanisms that Deliberately Pull Aflatoxin Out of Human Food Chains*. Twin and Twin Trading Ltd, London, UK Available at: www.twin.org.uk/sites/default/files/images/Liz-folder/documents/DFID-Malawi-report-for-web-0912.pdf

Engels, J.E. 2012. *Edible Oilseed Crop Guidebook for Uganda: Groundnut Production, Harvest and Post-harvest Handling*. Cultivating New Frontiers in Agriculture (CNFA), and United States Agency for International Development (USAID), Uganda.

Enyiukwu, D.N., Awurum, A.N. and Nwaneri, J.A. 2014. 'Efficacy of plant-derived pesticides in the control of myco-induced postharvest rots of tubers and agricultural products'. *Journal of Agricultural Science* 2 (1): 30–46.

Ephrem, G., Amare, A., Mashilla, D., Mengistu, K., Belachew, A. and Chemeda, F. 2014. 'Stakeholders' awareness and knowledge about aflatoxin contamination of groundnut (*Arachis hypogaea* L.) and associated factors in eastern Ethiopia'. *Asian Pacific Journal of Tropical Biomedicine* 4 (1): 930–937.

Eraslan, G., Akdogan, M., Yarsan, E., Sahindokuyucu, F., Essiz, D., and Altintas, L. 2005. The effects of aflatoxins on oxidative stress in broiler chickens. *Turkish Journal of Veterinary and Animal Sciences* 29: 701–707.

Eshetu, L. 2010. *Aflatoxin Content of Peanut (Arachis Hypogaea L.) in Relation to Shelling and Storage Practices of Ethiopian Farmers*. M.Sc. Thesis. Addis Ababa University, Addis Ababa, Ethiopia.

Essono, G., Ayodele, M., Akoa, A., Foko, J., Filtenborg, O. and Olembo, S. 2008. 'Aflatoxin-producing *Aspergillus* spp. and aflatoxin levels in stored cassava chips as affected by processing practices'. *Food Control* 20: 648–65.

Ethiopian Agricultural Research Organization (EARO). 2004. *Directory of Released Crop Varieties and their Recommended Cultural Practices*. EARO, Addis Ababa, Ethiopia.

Ethiopian Institute of Agricultural Research (EIAR). 2010. *Manual for Groundnut Production*. EIAR, Worer Agricultural Research Center, Ethiopia.

European Commission (EC). 1991. 'Commission Decision 91/180/EEC laying down certain methods of analysis and testing of raw milk and heat-treated milk'. *Official Journal of the European Communities* L93**:** 6–8.

European Commission (EC). 1998. 'Commission Directive 98/53/EC laying down the sampling methods and the methods of analysis for the official control of the levels for certain contaminants in foodstuffs'. *Official Journal of the European Communities* L201: 93–101.

Ezekiel, C.N., Sulyok, M., Babalola, D.A., Warth, B., Ezekiel, V.C. and Krska, R. 2013. 'Incidence and consumer awareness of toxigenic *Aspergillus* section Flavi and aflatoxin B_1 in peanut cake from Nigeria'. *Food Control* 30: 596–601.

Ezekiel, C.N., Sulyok, M., Warth, B., Odebode, A.C. and Krska, R. 2012. 'Natural occurrence of mycotoxins in peanut cake from Nigeria'. *Food Control* 27 (2): 338–342.

Ezekiel, C.N., Warth, B., Ogara, I.M., Bia, W.A., Ezekiel, V.C., Atehnkeng, J., Sulyok, M., Turner, P.C., Tayo, G.O., Krska, R. and Bandyopadhyay, R. 2014. 'Mycotoxin exposure in rural residents in northern Nigeria: A pilot study using multi-urinary biomarkers'. *Environment International* 66: 138–145.

Fandohan, P., Ahouansou, R., Houssou, P., Hell, K., Marasas, W.F.O. and Wingfield, M.J. 2006. 'Impact of mechanical shelling and dehulling on *Fusarium* infection and fumonisin contamination in maize'. *Food Additives and Contaminants* 23, 451–421.

Fandohan, P., Zoumenou, D., Hounhouigan, D.J., Marasas, W.F.O., Wingfield, M.J. and Hell, K. 2005. 'Fate of aflatoxins and fumonisins during the processing of maize into food products in Benin'. *International Journal of Food Microbioloy* 98: 249–259.

FAOSTAT. 2008. *Statistical Database*. Available at: http://faostat.fao.org [Accessed April 2010].

FAOSTAT. 2009. *Statistical Database*. Available at: http://faostat.fao.org [Accessed April 2010].

FAOSTAT. 2010. *Groundnut World Production*. Available at: http://www.faostat.fao.org

FAOSTAT. 2012. *Statistical Database*. Available at: http://faostat.fao.org [Accessed 5 December 2013].

FAOSTAT. 2014. *Africa Maize Production 2012/13*. Available at: http://faostat3.fao.org/browse/Q/QC/E [Accessed 10 November 2014].

Fitzgerald, G. 2015. Part 1: *The Production of Ready to Use Therapeutic Food in Malawi: Smallholder farmers' experience with groundnut production Results from a four year livelihoods analysis in Malawi's Central Region*. University College Cork, Cork, Ireland.

Flett, B.C., Ncube, E., Janse van Rensburg, B. and Phokane, S. 2015. *Aflatoxins in South Africa*. Agricultural Research Council – Grain Crops Institute, Potchefstroom, South Africa. Available at: http://programmes.comesa.int/attachments/article/173/South%20Africa_Brad%20Malawi%20aflatoxinTalk%202014%20presentation.pdf [Accessed 14 January 2016].

Food and Agriculture Organization of the United Nations (FAO). 1988. *Aflatoxin in Kenya*. FAO, Rome, Italy. Available at: http://agris.fao.org/aos/records/QY870004888

Food and Agriculture Organization of the United Nations (FAO). 2001. *Manual on the Application of the HACCP System in Mycotoxin Prevention and Control*. Food and Nutrition Paper 73. FAO, Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). 2003. *World Geography of Peanuts*. FAO, Rome, Italy. Available at: http://faostat.fao.org/beta/en/#data/QC [Accessed 22 October 2016].

Food and Agriculture Organization of the United Nations (FAO). 2012. *Analysis of Incentives and Disincentives for Groundnuts in Malawi*. Monitoring African Food and Agricultural Policies. FAO, Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). 2012. *FAO Statistical Yearbook*. FAO, Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) and World Food Programme (WFP). 2010. *Crop and Food Security Assessment Mission to Ethiopia*. FAO, Rome, Italy. Available at: http://www.faostat.fao.org

Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). 2005a. 'Practical actions to promote food safety'. Paper presented at the *Regional Conference on Food Safety for Africa,* 3–6 October 2005, Harare, Zimbabwe.

Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). 2005b. *'Situation analysis of food safety systems in Malawi'. Regional Conference on Food Safety for Africa.* 3–6 October 2005, Harare, Zimbabwe. FAO, WHO, Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) Codex Alimentarius. 2004. *General Standard for Contaminants and Toxins in Food and Feed (Codex Standard 1993–1995). Code of Practice for the Prevention and Reduction of Aflatoxin Contamination in Peanuts* (CAC//RCP 55--2004). Publisher, place of publication.

Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) and United Nations Environment Program (UNEP). 1999. *Mycotoxin Contamination of Foods and Feeds. An Overview*. Third Joint FAO/WHO/UNEP International Conference on Mycotoxin, Tunis, Tunisia, 3–6 March 1999.

Fountaina, J.C., Pawan, K., Liming, Y., Spurthi, N.N., Brian, T.S., Robert, D.L., Cheng, Z.Y., Robert, C.K., Rajeev, K.V. and Baozhu, G. 2015. 'Resistance to *Aspergillus flavus* in maize and peanut: Molecular biology, breeding, environmental stress, and future perspectives'. *The Crop Journal* 3: 229–237.

Frisvad, J.C., Houbraken, J. and Samson, R.A. 1999. '*Aspergillus* species and aßa-toxin production: area appraisal'. *In* Tuijtelaars, A.C.J. (ed.) *Food Microbiology and Food Safety into the Next Millennium*. Foundation Food Micro '99, Zeist, The Netherlands.

Frisvad, J.C. and Samson, R.A. 2004. '*Emericella venezuelensis*, a new species with stellate ascospores producing sterigmatocystin and aflatoxin B_1'. *Systematic and Applied Microbiology* 27: 672–680.

Frisvad, J.C., Skouboe, P. and Samson, R.A. 2005. 'Taxonomic comparison of three different groups of aflatoxin producers and a new efficient producer of aflatoxin B_1, sterigmatocystin and3-O-methylsterigmatocystin, *Aspergillus rambellii* sp. nov'. *Systematic and Applied Microbiology* 28: 442–453.

Fukal, L., Prosek, J. and Sova, Z. 1987. 'The occurrence of aflatoxins in peanuts imported into Czechoslovakia for human consumption'. *Food Additives Contaminants* 4: 285–289.

Fufa, H. and Urga, K. 1996. 'Screening of aflatoxins in Shiro and ground red pepper in Addis Ababa'. *Ethiopian Medical Journal* 34 (4): 243–9.

Fufa. H. and Urga, K. 2001. 'Survey of aflatoxin contamination in Ethiopia'. *Ethiopian Journal of Health Sciences* 11 (1): 17–25.

Galvano, F., Galofaro, V., Ritieni, A., Bognanno, M., De Angelis, A. and Galvano, G. 2001. 'Survey of the occurrence of aflatoxin M_1 in dairy products marketed in Italy: second year of observation'. *Food Additives Contaminants* 18: 644–646.

Garcia, D., Ramos, A.J., Sanchis, V. and Marín, S. 2009. 'Predicting mycotoxins in foods: A review'. *Food Microbiology* 26: 757–769.

Gbèhounou, G. 1998. *Seed ecology of Striga hermonthica in the Republic of Benin: Host Specificity and Control Potential*. PhD Thesis. Vrije Universiteit Amsterdam, Amsterdam, The Netherlands.

Gbèhounou, G. and E. Adango, 2003. 'Trap crops of *Striga hermonthica*: In vitro identification and effectiveness in situ'. *Crop Protection* 22: 395–404.

Gbodi, T.A. 1986. *Studies of Mycoflora and Mycotoxins in Acha, Maize and Cotton Seed in Plateau State, Nigeria*. PhD thesis. Department of Physiology and Pharmacology, Faculty of Veterinary Medicine, A.B.U, Zaria, Nigeria.

Gbodi, T.A., Nwude, N., Aliu, Y.O. and Ikediobi, C.O. 1984. 'Mycotoxins and Mycotoxicoses, the Nigerian situation to date'. Presented at the *National Conference on Disease of Ruminant*, 3–6 October 1984. National Veterinary Research Institute, Vom, Nigeria.

Gebreselassie R, Dereje, A. and Solomon, H. 2014. 'On farm pre harvest agronomic management practices of *aspergillus* infection on groundnut in Abergelle, Tigray'. *Journal of Plant Pathology and Microbiology* 5: 2.

Geiser, D.M., Dorner, J.W., Horn, B.W. and Taylor, J.W. 2000. 'Thephylogenetics of mycotoxin and sclerotium production in *Aspergillusflavus* and *Aspergillus oryzae'. Fungal Genetics and Biology* 31: 169–179.

Georges, N., Fang, S., Beckline, M. and Wu, Y. 2016. 'Potentials of the groundnut sector towards achieving food security in Senegal'. *Open Access Library Journal*, *3*: e2991.

Getnet, Y., Amare, A. and Nigussie, D. 2013. 'Management of aflatoxigenic fungi in groundnut production in eastern Ethiopia'. *East African Journal of Sciences* 7 (2): 85–98.

Ghewande, M.P. 1997. 'Aflatoxin contamination of groundnut and its management in India. Aflatoxin contamination problem in groundnut in Asia'. *Proceedings of the First Asia Working Group Meeting*, 27–29 May 1996.

Girgis, A.N., El-Sherif, S., Rofael, N. and Nesheim, S. 1977. 'Aflatoxins in Egyptian foodstuffs'. *Journal-Association of Official Analytical Chemists* 60 (3): 746–747.

Gizachew, D., Szonyi, B., Tegegne, A., Hanson, J. and Grace, D. 2015. 'Aflatoxin contamination of milk and dairy feeds in the Greater Addis Ababa milk shed, Ethiopia'. *Food Control* 59: 773–779.

Glaston, K.M., Mvula, M.A., Koaze, H. and Baba, N. 2000. 'Aflatoxin contamination of Kenyan maize flour and malted Kenyan and Malawian grains'. *Scientific Reports of the Faculty of Agriculture, Okayama University* 89: 1–7.

Gnonlonfin, G.J.B., Adjovi, C.S.Y., Katerere, D.R., Shephard, G.S., Sanni, A. and Brimer, L. 2012. 'Mycoflora and absence of aflatoxin contamination of commercialized cassava chips in Benin, West Africa'. *Food Control* 23 (2): 333–337.

Gnonlonfin, G.J.B., Hell, K., Adjovi, Y., Fandohan, P., Koudande, D.O., Mensah, G.A. and Brimer, L. 2013. 'A review on aflatoxin contamination and its implications in the developing world: A sub-Saharan African perspective'. *Critical Reviews in Food Science and Nutrition* 53 (4): 349–365.

Gonçalves, S.S., Stchigel, A.M., Cano, J.F., Godoy-Martinez, P.C., Colombo, A.L. and Guarro, J. 2012. '*Aspergillus novoparasiticus*: a new clinical species of the section Flavi'. *Medical Mycology* 50 (2): 152–160.

Gong, Y., Hounsa, A., Egal, S., Turner, P.C., Sutcliffe, A.E., Hall, A.J. and Wild, C.P. 2004. 'Postweaning exposure to aflatoxin results in impaired child growth: a longitudinal study in Benin, West Africa'. *Environmental Health Perspectives* 112 (13): 1334–1338.

Gong, Y.Y., Cardwell, K., Hounsa, A., Egal, S., Turner, P.C., Hall, A.J. and Wild, C.P. 2002. 'Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study'. *British Medical Journal* 325 (7354): 20–21.

Gong, Y.Y., Egal, S., Hounsa, A., Turner, P.C., Hall, A.J., Cardwell, K.F. and Wild, C.P. 2003. 'Determinants of aflatoxin exposure in young children from Benin and Togo, West Africa: the critical role of weaning'. *International Journal of Epidemiology* 32 (4): 556–562.

Gordon, S.S. 2003. 'Aflatoxin and food safety: Recent African perspectives. Promec Unit, Medical Research Council, Tygerberg, South Africa'. *Journal of Toxicology* 22: 264 – 268.

Gray, J.K. 2002. *The Groundnut Market in Senegal: Examination of Price and Policy Changes*. PhD Thesis. Virginia Tech, Virginia, USA.

Grenier, B. and Applegate, T.J. 2015. *Reducing the Impact of Aflatoxins in Livestock and Poultry*. Purdue University Department of Animal Sciences, Indiana, USA. Available at: https://www.extension.purdue.edu/extmedia/AS/AS-614-W.pdf [Accessed 4 November 2015].

Grenier, B., Loureiro, B.A.P. and Oswald, I.P. 2012. 'Physical and chemical methods for mycotoxin decontamination in maize'. *In* Logrieco, A.F. and Logrieco, L. (eds.) *Mycotoxin Reduction in Grain Chains: A Practical Guide.* Wiley Blackwell, London, UK.

Groopman, J.D. and Kensler, T.W. 2005. 'Role of metabolism and viruses in aflatoxin-induced liver cancer'. *Toxicology and Applied Pharmacology* 206 (2): 131–137.

Groopman, J.D., Wogan, G.N., Roebuck, B.D. and Kensler, T.W. 1994. 'Molecular biomarkers for aflatoxins and their application to human cancer prevention'. *Cancer Research* 54 (7): 1907s–1911s.

Guezlane-Tebibel, N., Bouras, N., Mokrane, S., Benayad, T. and Mathieu F. 2012. 'Afatoxigenic strains of *Aspergillus* section *Flavi* isolated from marketed peanuts (*Arachishypogaea*) in Algiers (Algeria)'. *Annals of Microbiology* 62: 1–11.

Guo, B., Chen, Z.Y., Dewey, R.L. and Brian, T.S. 2008. 'Drought stress and preharvest aflatoxin contamination in agricultural commodity: genetics, genomics and proteomics'. *Journal of Integrative Plant Biology* 50 (10): 1281–1291.

Gürbay, A., Sabuncuoğlu, S.A., Girgin, G., Şahin, G., Yiğit, Ş., Yurdakök, M. and Tekinalp. G, 2010. 'Exposure of newborns to aflatoxin M 1 and B 1 from mothers' breast milk in Ankara, Turkey'. *Food and Chemical Toxicology* 48 (1): 314–319.

Haggblade, S. and Dewina, R. 2010. 'Staple food prices in Uganda'. Prepared for the Comesa policy seminar on *Variation in Staple Food Prices: Causes, Consequence, and Policy Options*, 25–26 January 2010, Maputo, Mozambique.

Hain, J., Logan, L. and Collins, S. 2015. *Evaluation of Sanitary and Phytosanitary (SPS) Trade Policy Constraints Within the Maize and Livestock/Animal-Sourced Products Value Chains in East Africa*. United States Agency for International Development (USAID), Washington, DC, USA.

Hall, A.J. and Wild, C.P. 1994. 'Epidemiology of aflatoxin-related disease'. *In* Eaton, D.L. and Groopman, J.D. (eds.) 1994. *The Toxicology of Aflatoxins: Human Health, Veterinary, and Agricultural Significance.* Academic Press, London, UK.

Hanak, E., Boutrif, E., Fabre, F. and Pineiro, M. 2002. *Food Safety Management in Developing Countries*. Proceedings of the International Workshop, CIRAD-Food and Agriculture Organization of the United Nations (FAO), 11–13 December, Montpellier, France.

Harvey, J., Gnonlonfin, B., Fletcher, M. and Fox, G. 2013. 'Improving diagnostics for aflatoxin detection'. *IFPRI 2020 Focus Brief* 20 (19): 1-2.

Hatem, N.L., Hassab, H., Abd Al-Rahman, E.M., El-Deeb, S.A. and El-Sayed Ahmed, R.L. 2005. 'Prevalence of aflatoxins in blood and urine of Egyptian infants with protein–energy malnutrition'. *Food and Nutrition Bulletin* 26 (1): 49–56.

Heathcote, J.G. and Dutton, M.F. 1969. 'New metabolites of *Aspergillus flavus' Tetrahedron* 25: 1497–1500.

Heathcote, J.G. and Hibbert, J.R. 1978. *Aflatoxins: Chemical and Biological Aspects*. Elsevier Scientific Publishing Co. London, UK.

Hell, K. 2015. Scoping study to assess the policy environment and capacity for aflatoxin control in the ECOWAS member states. Partnership for Aflatoxin Control in Africa (PACA), Addis Ababa, Ethiopia.

Hell, K., Bandyopadhyay, R., Kiewnick, S., Coulibaly, O., Menkir, A. and Cotty, P. 2005. 'Optimal management of mycotoxins for improving food safety and trade of maize in West Africa'. *In* Tielkes, E., Hiilsebusch, C., Hauser, I., Deininger, A. and Becker, K. (eds.) *The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies*. Universitat Hohenheim, Tropenzentrum, Centre for Agriculture in the Tropics and Subtropics, Stuttgart, Germany. Available at: http://www.proceedings2005.tropentag.de

Hell, K., Cardwell, K.F. and Poehling, H.M. 2003. 'Distribution of fungal species and aflatoxin contamination in stored maize in four agroecological zones in Benin, West Africa'. *Journal of Phytopathology* 151: 690–698.

Hell, K., Cardwell, K.F., Setamou, M. and Poehling, H.M. 2000a. 'The influence of storage practices on aflatoxin contamination in maize in four agro ecological zones of Benin, West Africa'. *Journal of Stored Products Research* 36 (4): 365–382.

Hell, K., Cardwell, K.F., Setamou, M., Poehling, H.M, and Mutegi, C. 2011. 'Review: Aflatoxin control and prevention strategies in Kenya crops of sub-Sahara Africa'. *African Journal of Microbiology Research* 5(5): 459–466.

Hell, K., Cardwell, K.F., Setamou, M. and Schulthess, F. 2000b. 'Influence of insect infestation on aflatoxin contamination of stored maize in four agroecological regions in Benin'. *African Entomolology* 6: 169–177.

Hell, K., Fandohan, P., Bandyopadhyay, R., Cardwell, K., Kiewnick, S., Sikora, R. and Cotty, P. 2008. 'Pre- and post-harvest management of aflatoxin in maize'. *In* Leslie, J.F., Bandyopadhyay, R. and Visconti, A. (eds) *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*. CABI Publishing, Wallingford, UK.

Hell, K., Gnonlonfin, B.G.J., Kodjogbe, G., Lamboni, Y. and Abdourhamane, I.K. 2009. 'Mycoflora and occurrence of aflatoxin in dried vegetables in Benin, Mali and Togo, West Africa'. *International Journal of Food Microbiology* 135 (2): 99–104.

Hell, K. and Mutegi, C. 2011. 'Aflatoxin control and prevention strategies in key crops of Sub-Saharan Africa'. *African Journal of Microbiology Research* 5 (5): 459–466.

Hendrickse, R.G. 1984. 'The influence of aflatoxins on child health in the tropics with particular reference to kwashiorkor'. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 78 (4): 427–35.

Hendrickse, R.G. 1991. 'Kwashiorkor: the hypothesis that incriminates aflatoxins'. *Pediatrics* 88: 376–9.

Hendrickse, R.G., Coulter, J.B., Lamplugh, S.M., Macfarlane, S.B., Williams, T.E., Omer, M.I. and Suliman, G.I. 1982. 'Aflatoxins and kwashiorkor: a study in Sudanese children'. *British Medical Journal* 285 (6345): 843–846.

Henson, J.S., Brouder, A.M. and Mitullah, W. 2000. 'Food safety requirements and food exports from developing countries: The case of fish exports from Kenya to the European Union'. *American Journal of Agricultural Economics* 82 (5): 1159–69. Available at: http://www.fao.org/fileadmin/user_upload/agns/news_events/Pre_CCAFRICA_KenyaEN.pdf

Herman, T. 2016. 'Providing safe maize for Africa: Aflatoxin proficiency testing and control in Africa project at the BecA-ILRI Hub'. *BecA-ILRI Hub* [online], 10 June 2016. Available at: http://hub.africabiosciences.org/blog/providing-safe-maize-for-africa-aflatoxin-proficiency-testing-and-control-in-africa-project-at-the-beca-ilri-hub/

Hichaambwa, M. and Jayne T.S. 2012. *Smallholder Commercialization Trends as Affected by Land Constraints in Zambia: What are the Policy Implications?* Working Paper 61. Indaba Agricultural Policy Research Institute (IAPRI), Lusaka, Zambia. Available at: http://pdf.usaid.gov/pdf_docs/pnadz179.pdf [Accessed on 22 October 2016].

Hill, R.A., Blankenship, P.D., Cole, R.J. and Sanders, T.H. 1983. 'Effects of soil moisture and temperature on preharvest invasion of the *Aspergillus flavus* group and subsequent aflatoxin development'. *Applied Environmental Microbiology* 45: 628–638.

Hill, R.A., Wilson, D.M., Burg, W.R. and Shotwell, O.L. 1984. 'Viable fungi in corn dust'. *Applied and Environmental Microbiology* 47: 84–87.

Hoffmann, V., Jones, K.M. and Leroy, J.L. 2014. *Mitigating Aflatoxin Exposure to Improve Child Growth in Eastern Kenya*. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/publication/mitigating-aflatoxin-exposure-improve-child-growth-eastern-kenya

Holbrook, C.C., Kvien, C.K., Rucker, K.S., Wilson, D.M., Hook, J.E. and Matheron, M.E. 2000. 'Preharvest aflatoxin contamination in drought-tolerant and drought-intolerant peanut genotypes'. *Peanut Science* 27 (2): 45–48.

Holbrook, C.C., Matheron, M.E. Wilson, D.W., Anderson, W.F., Will, M.E. and Norden, A.J. 1994. 'Development of a large-scale field screening system for resistance to pre-harvest aflatoxin contamination'. Peanut Science 21: 20–22.

Horn, B.W. 2003. 'Ecology and population biology of aflatoxigenic fungi in soil'. *Journal of Toxicology Toxin Reviews* 22 (2–3): 351–379.

Houssou, P.A., Ahohuendo, B.C., Fandohan, P., Kpodo, K., Hounhouigan, D.J. and Jakobsen, M. 2009. 'Natural infection of cowpea (*Vigna unguiculata* (L.) Walp.) by toxigenic fungi and mycotoxin contamination in Benin, West Africa'. *Journal of Stored Products Research* 45 (1): 40–44.

Hsieh, D.P.H., Wong, Z.A., Wong, J.J., Michas, C. and Ruebner, B.H. 1977. 'Comparative metabolism of aflatoxin'. *In* Rodricks, J.V., Hesseltine, C.W. and Mehlman, M.A. (eds.) *Mycotoxins in Human and Animal Health*. Pathotox, Park Forest South, Illinois, USA.

Hudson, G.J., Wild, C.P., Zarba, A. and Groopman, J.D. 1992. 'Aflatoxins isolated by immunoaffinity chromatography from foods consumed in The Gambia, West Africa'. *Natural Toxins* 1 (2): 100–105.

Huwig, A., Freimund, S., Käppeli, O. and Dutler H, 2001. 'Mycotoxin detoxication of animal feed by different adsorbents'. *Toxicology Letters* 122 (2): 179–188.

Idahor, K.O. and Ogara, I.M. 2010. 'Tiv people awareness of mycotoxins occurrence in food crops produced in the Lower Benue Basin'. Paper presented at 5th *Annual Conference of the Nigeria Mycotoxin Awareness and Study Network*. Nigerian Stored Products Research Institute, Ilorin, Nigeria.

Idris, Y.M., Mariod, A.A., Elnour, I.A. and Mohamed, A.A. 2010. 'Determination of aflatoxin levels in Sudanese edible oils'. *Food and Chemical Toxicology* 48 (8): 2539–2541.

Ifeji, E., 2012. *Fungi and Some Mycotoxins Found in Groundnuts (*Arachis Hypogea*) From Niger State, Nigeria*. M. Tech Dissertation. Department of Biochemistry, Federal University of Technology, Minna, Nigeria.

Ifeji, E.I, Makun, H.A, Mohammed, H.L, Adeyemi, R.Y.H, Mailafiya, S.C., Mohammad, K.H. and Olurunmowaju, Y.B. 2014. 'Natural occurrence of aflatoxins and ochratoxin A in raw and roasted groundnut from Niger State, Nigeria'. *Mycotoxicology 1: 35–45.*

Ikwuegbu, O.A. 1984. 'Two decades of Aflatoxin Research in Vom'. Presented at the *National Conference on Diseases of Ruminants*, 03–06 October 1984, National Veterinary Research Institute, Vom, Nigeria.

Ilesanmi, F.F. and Ilesanmi, S.O. 2011. 'Knowledge of aflatoxin contamination in groundnut and the risk of its ingestion among health workers in Ibadan, Nigeria'. *Asian Pacific Journal of Tropical Biomedicine* 1 (6): 493–495.

Ilunga, K., Mngqawa, P., Rheeder, J.P., Teffo, S.L. and Katerere, D.R. 2014. 'Mycological and aflatoxin contamination of peanuts sold at markets in Kinshasa, Democratic Republic of Congo, and Pretoria, South Africa'. *Food Additives & Contaminants* Part B**7** (2): 120–126.

Imwidthaya, S., Anukarahanonta, T. and Komolpis, P. 1987. 'Bacterial, fungal and aflatoxin contamination of cereals and cereal products in Bangkok'. *Journal of the Medical Association of Thailand* 70: 390–396.

International Agency for Research on Cancer (IARC). 2002. 'IARC summaries and evaluations.' *Aflatoxins* 82: 171.

International Agency for Research on Cancer (IARC). 2012a. *Monographs on The Evaluation of Carcinogenic Risks to Humans*. IARC Press, Lyon, France.

International Agency for Research on Cancer (IARC). 2012b. 'Analysis of mycotoxins'. *In* Pitt, J.I., Wild, C.P., Baan, R.A., Gelderblom, W.C.A., Miller, D.J., Riley, R.T. and Wu, F. (eds.) *Improving Public Health Through Mycotoxin Control*. IARC Press, Lyon, France.

International Agency for Research on Cancer (IARC). 2012c. 'Sampling and sample preparation methods for determining concentrations of mycotoxins in foods and feeds'. *IARC Scientific Publications* 158: 39–51.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 2006. 'Nurturing the seeds of success in the semi-arid tropics'. *In* ICRISTAT *Annual Report*. ICRISAT, Andhra Pradesh, India.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 2009. *Aflatoxin Testing Kit: Protects Human Health, Helps Meet International Market Standards*. ICRISAT, Andhra Pradesh, India. Available at: http://www.icrisat.org/impacts/impact-stories/icrisat-is-aflotoxin-kit.pdf

International Institute of Tropical Agriculture (IITA). 2012. *Tackling killer Aflatoxins in African Food Crops*. Available at: http://www.iita.org/c/document_library/get_file?p_l_id=25368&folderId=1999946&name=DLFE-5707.pdf&version=1.0 [Accessed 27 October 2016].

International Maize and Wheat Improvement Center (CIMMYT). 2015. 'The drought tolerant maize initiative'. *CIMMYT* [online]. Available at: http://dtma.cimmyt.org/index.php/about/background

International Maize and Wheat Improvement Center (CIMMYT), United Nations Development Programme (UNDP), and the United States Agency for International Development (USAID). 1986. *Aflatoxins in Maize. A Proceedings of the Workshop El Batan, Mexico, 7–11 April*. CIMMYT, Mexico City, Mexico.

International Trade Centre (ITC). 2013. 'Boosting the value of groundnuts in the Gambia'. *In International Trade Centre Annual Report 2013*. ITC, Geneva, Switzerland.

Intertek. 2012. *Food & Agriculture Services* [online]. Available at: http://www.intertek.com/food/ [Accessed 28 August 2012].

Islamic Republic of The Gambia. 2009. *Agriculture and Natural Resources (ANR) Policy (2009–2015)*. The Islamic Republic of The Gambia, Banjul, The Gambia.

Ito, Y., Peterson, S.W., Wicklow, D.T. and Goto, T. 2001. '*Aspergillus pseudotamarii*, a new aflatoxin producing species in *Aspergillus* section flavi'. *Mycological Research* 105 (02): 233–239.

Jabbar, M. and Delia, G. 2012. 'Regulations for safety of animal source foods in selected Sub-Saharan African countries: Current status and their implications'. Paper prepared for presentation at the *The Safe Food, Fair Food Project*, January 2012, International Livestock Research Institute, Nairobi, Kenya.

Jaime-Garcia, R. and Cotty, P.J. 2010. 'Crop rotation and soil temperature influence the community structure of *Aspergillus* flavus in soil'. *Soil Biology and Biochemistry* 42(10): 1842–1847.

James, B. 2005. *Public Awareness of Aflatoxin and Food Quality Control in Benin*. International Institute of Tropical Agriculture, Benin.

James, B., Adda, C., Cardwell, K., Annang, D., Hell, K., Korie, S. and Houenou, G. 2007. 'Public information campaign on aflatoxin contamination of maize grains in market stores in Benin, Ghana and Togo'. *Food Additives and Contaminants* 24 (11): 1283–1291.

Jammeh, S.C. 1987. 'Politics of agricultural price decision making in Senegal'. *In* Waterbury, J. and Gersovitz, M. (eds.) *The Political Economy Risk and Choice in Senegal*. Frank Cass, London, UK.

Jensen, M.F. and Yu, W. 2012. *Regional Trade Integration in Africa: Status and Prospects*. Ministry of Foreign Affairs of Denmark, Copenhagen, Denmark.

Jewers, K. 2015. *Mycotoxins and Their Effect on Poultry Production*. Tropical Development and Research Institute (TDRI), London, UK. Available at: http://www.2ndchance.info/goutjewersmycotoxins.pdf

Jolly, P., Jiang, Y., Ellis, W., Awuah, R., Nnedu, O., Phillips, T. and Jolly, C. 2006. 'Determinants of aflatoxin levels in Ghanaians: Sociodemographic factors, knowledge of

aflatoxin and food handling and consumption practices'. *International Journal of Hygiene and Environmental Health* 209 (4): 345–358.

Jonsyn, F.E. 1989. 'Fungi associated with selected fermented foods in Sierra Leone'. *MIRCEN Journal of Applied Microbiology and Biotechnology* 5 (4): 457–462.

Jonsyn, F.E. 1999. 'Intake of aflatoxins and ochratoxins by infants in Sierra Leone: Possible effects on the general health of these children'. *Journal of Nutritional and Environmental Medicine* 9 (1): 15–22.

Jonsyn, F.E. and Lahai, G.P. 1992. 'Mycotoxic flora and mycotoxins in smoke-dried fish from Sierra Leone'. *Food/Nahrung* 36 (5): 485–489.

Jonsyn, F.E., Maxwell, S.M. and Hendrickse. R.G. 1994. 'Human fetal exposure to ochratoxin A and aflatoxins'. *Annals of Tropical Paediatrics* 15 (1): 3–9.

Jonsyn, F.E., Maxwell, S.M. and Hendrickse, R.G. 1995. 'Ochratoxin A and aflatoxins in breast milk samples from Sierra Leone'. *Mycopathologia* 131 (2): 121–126.

Jonsyn-Ellis, F.E. 2000. 'Aflatoxins and ochratoxins in urine samples of school children in Mokonde, Southern Sierra Leone'. *Journal of Nutritional and Environmental Medicine* 10 (3): 225–31.

Juan, C., Zinedine, A., Moltó, J.C., Idrissi, L. and Mañes, J. 2008. 'Aflatoxin levels in dried fruits and nuts from Rabat-Salé area, Morocco'. *Food Control* 19 (9): 849–53.

Juan-Lopez, M., Carvajal, M. and Ituarte, B. 1995. 'Supervising programme of aflatoxins in Mexican corn'. *Food Additives & Contaminants* 12: 297–312.

Jukes, D.J. 1988. 'Developing a food control system - The Tanzanian experience'. *Food Policy* 13 (3): 293–304

Kaaya, A.N., Harris, C. and Eigel, W. 2006. 'Peanut aflatoxin levels on farms and in markets of Uganda'. *Peanut Science* 33 (1): 68–75.

Kaaya, A.N. and Kyamuhangire, W. 2006. 'The effect of storage time and agroecological zone on mould incidence and aflatoxin contamination of maize from traders in Uganda'. *International Journal of Food Microbiology* 110: 217– 223.

Kaaya, A.N., Kyamuhangire, W. and Kyamanywa, S. 2006. 'Factors affecting aflatoxin contamination of harvested maize in the three agroecological zones of Uganda'. *Journal of Applied Sciences* 6: 2401–2407.

Kaaya, A.N. and Muduuli, D.S. 1992. *Aflatoxin Incidence in Grains, Roots and Tubers of Uganda*. Manpower for Agriculture Development (MFAD) Report, Faculty of Agriculture and Forestry, Makerere University, Kampala, Uganda.

Kaaya, A.N and Warren, H.L. 2005. 'A review of past and present research on aflatoxin in Uganda'. *African Journal of Food Agriculture and Nutritional Development (AJFAND): Volume* 5 (1): 1–18.

Kaaya, A.N., Warren, H., Adipala, E., Kyamanywa, S., Agona, J.A. and Bigirwa, G. 2001. 'Mould incidence and mycotoxin contamination of maize and groundnuts in Mayuge and Kumi districts of Uganda'. *African Crop Science Conference Proceedings* 5: 507–512.

Kaaya, A.N., Warren, H.L., Kyamanywa, S. and Kyamuhan, W. 2005. 'The effect of delayed harvest on moisture content, insect damage, moulds and aflatoxin contamination of maize

in Mayuge district of Uganda'. *Journal of the Science of Food and Agriculture* 85: 2595–2599.

Kabak, B. 2010. 'Prevention and management of mycotoxins in food and feed'. *Mycotoxins in Food, Feed and Bioweapons* 2: 201–27.

Kabbashi, E.B.M. and Ali, S.E.E. 2014. 'Aflatoxins in groundnut paste in Khartoum State, Sudan'. *US Open Food Science & Technology Journal* 1 (3): 1–8.

Kamala, A., Kimanya, M., Haesaert, G., Tiisekwa, B., Madege, R., Degraeve, S., Cyprian, C. and De Meulenaer, B. 2016. 'Local post-harvest practices associated with aflatoxin and fumonisin contamination of maize in three agro ecological zones of Tanzania'. *Food Additives & Contaminants: Part A* 33(3): 551–559.

Kamala, A., Ortiz, J., Kimanya, M., Haesaert, G., Donoso, S., Tiisekwa, B. and De Meulenaer, B. 2015. 'Multiple mycotoxin co-occurrence in maize grown in three agro-ecological zones of Tanzania'. *Food Control* 54: 208–215.

Kamika, I. and Takoy, L.L. 2011. 'Natural occurrence of Aflatoxin B_1 in peanut collected from Kinshasa, Democratic Republic of Congo'. *Food Control* 22 (11): 1760–1764.

Kana, J.R., Gnonlonfin, B.G.J., Harvey, J., Wainaina, J., Wanjuki, I., Skilton, R.A. and Teguia, A. 2013. 'Assessment of aflatoxin contamination of maize, peanut meal and poultry feed mixtures from different agroecological zones in Cameroon'. *Toxins* 5 (5): 884–894.

Kane, A. 1996. 'Aflatoxin in crude groundnut oil: occurrence and elimination'. *In* Waliyar, F. (eds.) *Summary Proceedings of the Fourth ICRISAT Regional Groundnut Meeting for Western and Central Africa*, *29 November–2 December 1994, ICRISAT Sahelian Center, Niamey, Niger*. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India.

Kang, M.S., Nkurunziza, P., Muwanika, R., Qian, G., Tang, L., Song, X. and Wang, J.S. 2015. 'Longitudinal evaluation of aflatoxin exposure in two cohorts in south-western Uganda'. *Food Additives & Contaminants Part A* 32 (8): 1322–1330.

Kang'ethe, E. 2011. *Situational Analysis: Improving Food Safety in The Maize Value Chain In Kenya*. University of Nairobi, Nairobi, Kenya. Available at: http://www.fao.org/fileadmin/user_upload/agns/pdf/WORKING_PAPER_AFLATOXIN_REPORTDJ10thOctober.pdf

Kang'ethe, E.K. and Lang'a, K.A. 2009. 'Aflatoxin B_1 and M_1 contamination of animal feeds and milk from urban centers in Kenya'. *African Health Sciences* 9 (4): 218–226.

Kang'ethe, E.K., Arimi, S.M. and Kioko, P.M. 2011. *Safety of Animal Source Foods in Kenya – A Situational Analysis*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Kang'ethe, E.K., M'ibui, G.M., Randolph, T.F. and Lang'a, A.K. 2007. 'Prevalence of aflatoxin M_1 and B_1 in milk and animal feeds from urban smallholder dairy production in Dagoretti division, Nairobi, Kenya'. *East African Medical Journal* 84 (11): S83–6.

Kassie, M., Shiferaw, B. and Muricho, G. 2010. *Adoption and Impact of Improved Groundnut Varieties on Rural Poverty. Evidence from Rural Uganda*. Environment for Development, Sweden.

Katundu, M.A., Mhina, M.L., Mbeiyererwa, A.G. and Kumburu, N.P. 2012 'Agronomic factors limiting groundnut production: A case of smallholder farming in Tabora Region. Presented

at *REPOA's 17th Annual Research Workshop*, 28–29 March 2012, Dar es Salaam, Tanzania.

Kaushal, K.S. and Bhatnagar, D. 1998. *Mycotoxins in Agriculture and Food Safety*. CRC Press, London, UK.

Keetch, D.P., Webster, J.W., Ngqaka, A., Akanbi, R. and Mahlangu, P. 2005. 'Bt maize for small scale farmers: A case study'. *African Journal of Biotechnology* 4 (13): 1505–1509.

Keita, C., Babana, A.H., Traoré, D., Samaké, F., Dicko, A.H., Faradji, F.A. and Diallo A. 2013. 'Evaluation of the sanitary quality of peanut butters from Mali: Identification and quantification of Aflatoxins and pathogens'. *Scientific Journal of Microbiology* 2 (8): 150–157.

Kenji, G.M., Mvula, A.M., Koaze, H. and Baba, N. 2000. 'Aflatoxin contamination of Kenyan maize flour and malted Kenyan and Malawian grains'. *Scientific Reports-Faculty of Agriculture Okayama University* 89: 5–8.

Kershaw, S.J. 1982. 'Occurrence of aflatoxins in oilseeds providing cocoa-butter substitutes'. *Applied and Environmental Microbiology* 43 (5): 1210–1212.

Khilosia, L.D. 2011. *A Surveillance Study of Mycotoxin in the South African Industry with Specific Reference to Aflatoxin B_1 in Feed and Aflatoxin M_1 in Farm Gate and Selected Commercially Available Dairy Milk*. Masters of Technology Dissertation. Faculty of Health Science, University of Johannesburg, South Africa.

Kichou, F. and Walser, M.M. 1993. 'The natural occurrence of aflatoxin B_1 in Moroccan poultry feeds'. *Veterinary and Human Toxicology* 35 (2): 105–108.

Kilonzo, R.M., Imungi, J.K., Muiru, W.M., Lamuka, P.O. and Njage, P.M.K. 2014. 'Household dietary exposure to aflatoxins from maize and maize products in Kenya'. *Food Additives & Contaminants Part A* 31(12): 2055–2062.

Kimanya, M.E., De Meulenaer, B., Tiisekwa, B., Ndomondo-Sigonda, M., Devlieghere, F., Van Camp, J. and Kolsteren, P. 2008. 'Co-occurrence of fumonisins with aflatoxins in home-stored maize for human consumption in rural villages of Tanzania'. *Food Additives & Contaminants* 25 (11): 1353–1364.

Kimanya, M. 2014. 'Aflatoxins challenge in Tanzania'. Paper presented at the *Regional Workshop on the Aflatoxin Challenge in Eastern and Southern Africa*, 11–13 March 2014, Lilongwe, Malawi.

King, S.B. and Scott, G.E. 1982. 'Field inoculation techniques to evaluate maize for reaction to kernel infection by *Aspergillus flavus*'. *Phytopathology* 72(7): 782–785.

Kitya, D., Bbosa, G.S. and Mulogo, E. 2010. 'Aflatoxin levels in common foods of South Western Uganda: a risk factor to hepatocellular carcinoma'. *European Journal of Cancer Care* 19 (4): 516–521.

Knight, R. and Sylla, F. 2011. *Oilseeds and Products Annual Update 2011*. United States Department of Agriculture Foreign Agricultural Service, Washington, DC, USA.

Koekoek, F.J. 2002. *Organic and Fairtrade Peanut Markets in Europe. Summary of a Market Study*. Export Promotion of Organic products from Africa (EPOPA), Bennekom, The Netherlands.

Kofi, E.A., Shadlia, M.M., Alan, A.C., Richard, F.T. and Ali, M.E. 2011. 'Occurrence of fungi and mycotoxins in some commercial baby foods in North Africa'. *Food and Nutrition Sciences* 27: 751–758.

Kouadio, J.H., Lattanzio, V.M.T., Ouattara, D., Kouakaou, B. and Visconti, A. 2014. 'Assessment of mycotoxin exposure in Côte d'Ivoire (Ivory Coast) through multi-biomarker analysis and possible correlation with food consumption patterns'. *Toxicology International* 21 (3): 248–257.

Kpodo, K.A. 1996. '*Mycotoxins in maize and fermented maize products in southern Ghana'. In* Cardwell, K.F. (eds.) *Proceedings of the Workshop on Mycotoxins in Foods in Africa*, 6–10 November 1995, Cotonou, Benin. International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

Kpodo, K.A. 1997. *Mycotoxin Management in Peanut by Prevention of Contamination and Monitoring.* Final report of the Food Research Institute (FRI) Texas A&M Peanut Collaborative Research Support Programme (Peanut CRSP) Project. United States Agency for International Development (USAID), Washington D.C., USA.

Kpodo, K.A. 2001. *Fusaria and Fumonisins in Maize and Fermented Maize Products in Ghana*. PhD Thesis. University of Ghana, Legon, Ghana.

Kpodo, K., Sorensen, A.K. and Jakobsen, M. 1996. 'The occurrence of mycotoxins m fermented maize products'. *Food Chemistry* 56: 147–153.

Kpodo, K., Thrane, U. and Hald, B. 2000. 'Fusaria and fumonisins in maize from Ghana and their co-occurrence with aflatoxins'. *International Journal of Food Microbiology* 61 (2): 147–157.

Kraybill, H.F. 1970. 'Toxicological problems in agriculture'. *In* Herzberg, M. (ed.) *Proceedings of the First U.S.-Japan Conference on Toxic Micro-organisms*, 7-10 October, 1968. UJNR Joint Panels on Toxic Micro-organisms and the U.S Department of the Interior, Honolulu Hawaii.

Krishnamachari, K.A.V.R., Nagarajan, V., Bhat, R. and Tilak, T.B.G. 1975. 'Hepatitis due to aflatoxicosis: An outbreak in western India'. *The Lancet* 305 (7915): 1061–1063.

Kudama, G. 2013. 'Economics of groundnut production in East Hararghe Zone of Oromia Regional State, Ethiopia'. *Science, Technology and Arts Research Journal* 2 (2): 135–139.

Kumi, J., Dotse, E., Asare, G.A. and Ankrah, N.A., 2015. 'Urinary aflatoxin M1 exposure in Ghanaian children weaned on locally prepared nutritional food'. *African Journal of Science and Research 4* (6): 28–32.

Kumi, J., Mitchell, N.J., Asare, G.A., Dotse, E., Kwaa, F., Phillips, T.D. and Ankrah, N.A. 2014. 'Aflatoxins and fumonisins contamination of home-made food (Weanimix) from cereal-legume blends for children'. *Ghana Medical Journal* 48 (3): 121–126.

Kuniholm, M.H., Lesi, O.A., Mendy, M., Akano, A.O., Sam, O., Hall, A.J., Whittle, H., Bah, E., Goedert, J.J., Hainaut, P. and Kirk, G.D. 2008. 'Aflatoxin exposure and viral hepatitis in the etiology of liver cirrhosis in the Gambia, West Africa'. *Environmental Health Perspectives* 116(11): 1553.

Kurtzman, C.P., Horn, B.W. and Hesseltine, C.W. 1987. '*Aspergillus nomius*, a new aflatoxin-producing species relatedto *Aspergillus flavus* and *Aspergillus parasiticus*. *Antonievan Leeuwenhoek* 53: 147–158.

Kurwijila, L.R., Mwingira, J., Karimuribo, E., Shirima, G., Lema, B., Royoba, R. and Kilima, B. 2011. *Safety of Animal Source Foods in Tanzania: A Situational Analysis*. Draft report submitted to International Livestock Research Institute (ILRI), Nairobi, Kenya.

Lamb, E. J., Omari, M. and Kocyn, S. 2015. *Aflatoxin Associated Postharvest Losses for Selected Food Security Crops in East Africa*. International Institute of Tropical Agriculture (IITA), Dar es Salaam, Tanzania. Available at: https://d3n8a8pro7vhmx.cloudfront.net/eatradehub/pages/517/attachments/original/1429600275/Aflatoxin_-_Post_harvest_Losses_for_Selected_Crops_in_EAC.002.pdf?1429600275 [Accessed 1 October 2016].

Lamboni, Y., Frisvad, J.C., Hell, K., Linnemann, A.R., Nout, R.M., Tamo, M., Nielsen, K.F., van Boekel, M.A. and Smid, E.J., 2016. 'Occurrence of *Aspergillus section Flavi* and section Nigri and aflatoxins in raw cashew kernels (*Anacardiumoccidentale* L.) from Benin'. *LWT-Food Science and Technology* 70: 71–77.

Lamplugh, S.M. and Hendrickse, R.G. 1982. 'Aflatoxins in the livers of children with kwashiorkor'. *Annals of Tropical Paediatrics* 2 (3): 101–104.

Lanyasunya, T.P., Wamae, L.W., Musa, H.H., Olowofeso, O. and Lokwaleput, I.K. 2005. 'The risk of mycotoxins contamination of dairy feed and milk on smallholder dairy farms in Kenya'. *Pakistan Journal of Nutrition* 4 (3): 162–169.

Leclercq, C., Piccinelli, R., Arcella, D. and Le Donne, C. 2004. 'Food consumption and nutrient intake in a sample of Italian secondary school students: results from the INRAN-RM-2001 food survey'. *International Journal of Food Sciences and Nutrition* 55 (4): 265–277.

Leroy, J.L., Wang, J.S. and Jones, K., 2015. 'Serum aflatoxin B 1-lysine adduct level in adult women from Eastern Province in Kenya depends on household socio-economic status: A cross sectional study'. *Social Science & Medicine 146:* 104–110.

Leslie, J.F., Bandyopadhyay, R. and Visconti, A. 2008. *Mycotoxin Detection Methods, Management, Public Health and Agricultural Trade*. CABI Publishing, Wallingford, UK.

Lesser, C. and and Moisé-Leeman, E. 2009. *Informal Cross-Border Trade and Trade Facilitation Reform in Sub-Saharan Africa: Final Report*, OECD Trade Policy Working Paper No. 86. Organisation for Economic Co-operation an Development (OECD) Publishing, Paris, France.

Lewis, L., Onsongo, M., Njapau, H., Schurz-Rogers, H., Luber, G. and Kieszak, S., Kenya Aflatoxicosis Investigation Group. 2005. 'Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in Eastern and Central Kenya'. *Environmental Health Perspectives* 113 (12): 1763–1767.

Lillehoj, E.B., Kwolek, W.F., Horner, E.S., Widstrom, N.W., Josephson, L.M., Franz, A.O. and Catalano, E.A. 1980a. 'Aflatoxin contamination of preharvest corn: Role of *Aspergillus flavus* inoculum and insect damage'. *Cereal Chem*istry 57: 255–257.

Lillehoj, E.B., Kwolek, W.F., Zuber, M.S., Bockholt, A.J., Calvert, O.H., Findley, W.R., Guthrie, W.D., Horner, E.S., Josephson, L.M., King, S., Manwiller, A., Sauer, D.B., Thompson, D.L.,

Turner, M. and Widstrom, N.W. 1980b. 'Aflatoxin in corn before harvest: Interaction of hybrids and locations'. *Crop Science* 20: 731–734.

Liu, Y. and Wu, F., 2010. 'Global burden of aflatoxin-induced hepatocellular carcinoma: A risk assessment'. Environmental Health Perspectives 118(6): 818.

Lopez, A. and Crawford, M.A. 1967. 'Aflatoxin content of groundnuts sold for human consumption in Uganda'. *The Lancet* 290 (7530): 1351–1354.

Lopez, A.R. and Hathie, I. 1998. 'Structural adjustment programs and peanut market performance in Senegal'. Selected paper, *American Agricultural Economics Association Meeting*, 2–5 August 1988, Salt Lake City, Utah, USA.

Lopez-Garcia, R. and Park, D.L. 1998. 'Effectiveness of post-harvest procedures in management of mycotoxin hazards'. *In* Bhatnagar, D. and Sinha, S. (eds.), *Mycotoxins in Agriculture and Food Safety*. Marcel Dekker, New York, USA.

Lubungu, M., Burke, W. and Sitko, N.J. 2013. *Analysis of the Soya Bean Value Chain in Zambia's Eastern Province*. Working Paper No. 74. Indaba Agricultural Policy Research Institute (IAPRI), Lusaka, Zambia.

Lugendo, T.B., Shenkalwa, M.E., Mapunda, X.T. and Matata, L.W. 2010. 'The groundnut client oriented research in Tabora, Tanzania'. *African Journal of Agricultural Research* 5 (5): 356–362.

Madbouly, A.K., Ibrahim, M.I., Sehab, A.F. and Abdel-Wahhab, M.A. 2012. 'Co-occurrence of mycoflora, aflatoxins and fumonisins in maize and rice seeds from markets of different districts in Cairo, Egypt'. *Food Additives and Contaminants Part B* 5 (2): 112–120.

Magoha, H., Kimanya, M., De Meulenaer, B., Roberfroid, D., Lachat, C. and Kolsteren, P. 2014. 'Association between aflatoxin M_1 exposure through breast milk and growth impairment in infants from Northern Tanzania'. *World Mycotoxin Journal* **7** (3): 277–284.

Makokha, A.O., Oniang'o, R.K., Njoroge, S.M. and Kamar, O.K. 2002. Effect of traditional fermentation and malting on phytic acid and mineral availability from *Sorghum bicolor* and finger millet *eleucine caracana* grain varieties grown in Kenya'. *Food and Nutrition Bulletin* 23: 241–245.

Makun, H.A., Anjorin, S.T., Moronfoye, B., Adejo, F.O., Afolabi, O.A., Fagbayibo, G., Balogun, B.O. and Surajudeen, A.A. 2010. 'Fungal and aflatoxin contaminations of some human food commodities in Nigeria'. *African Journal of Food Sciences* 4 (4): 127–135.

Makun, H.A., Dutton, M.F., Njobeh, P.B., Mwanza, M. and Kabiru, A.Y. 2011. 'Natural multi-mycotoxin occurrence in rice from Niger State, Nigeria'. *Mycotoxin Research* 27 (2): 97–104.

Makun, H.A., Gbodi, T.A., Akanya, H.O., Sakalo, A.E. and Ogbadu, G.H. 2009a. 'Health implications of toxigenic fungi found in two Nigerian staples: guinea corn and rice'. *African Journal of Food Science* 3: 250–256.

Makun, H.A., Gbodi, T.A., Akanya, H.O., Salako, E.A. and Ogbadu, G.H. 2009b. 'Fungi and some mycotoxins found in mouldy Sorghum in Niger State, Nigeria'. *World Journal of Agricultural Sciences* 5 (1): 05–17.

Makun, H.A., Sime, M.C., Abdulramoni, S.A., Chimeririm, O.B. and Uchenna, O.M. 2012. 'Preliminary survey of aflatoxin in fresh and dried vegetables in Minna, Nigeria'. *African Journal of Food Science and Technology* 3 (10): 268–272.

Makun, H.A., Timothy, A., Gbodi, O.H., Akanya, A.E., Salako, E.A. and Ogbadu, G.H. 2007. 'Fungi and some mycotoxins contaminating rice *(Oryza sativa*) in Niger State, Nigeria'. *African Journal of Biotechnology* 6(2): 99–108.

Manikandan, P., Varga, J., Kocsube, S., Samson, R.A., Anita, R., Revathi, R., Dczi, I., Nemeth, T.M., Narendran, V., Vgvslgyi, C., Manoharan, C. and Kredics, L. 2009. 'Mycotickeratitis due to *Aspergillus nomius'*. *Journal of Clinical Microbiology* 47: 3382–3385.

Maragos, C. and Busman, M. 2010. 'Rapid and advanced tools for mycotoxin analysis: a review'. *Food Additives and Contaminants* 27(5): 688–700.

Marasas, W.F.O. 1988. 'Medical relevance of mycotoxin in Southern Africa'. *Microbiologie Aliments Nutr*ition 6: 1–5.

Marnus, G., Carl, P.R., Schimmelpfennig, D. and Kirsten, J. 2006. 'Three seasons of subsistence insect-resistant maize in South Africa: have smallholders benefited?'. *AgBioForum* 9 (1): 15–22.

Martin, P.M.D. and Gilman, G.A. 1976. *A Consideration of the Mycotoxin Hypothesis With Special Reference to the Mycoflora of Maize, Sorghum, Wheat and Groundnuts (G105)*. Discussion Paper. Tropical Products Institute, London, UK. Available at: http://gala.gre.ac.uk/10792

Martins, M.L., Martins, H.M. and Bernardo, F. 2001. 'Aflatoxins in spices marketed in Portugal'. *Food Additives & Contaminants* 18 (4): 315–319.

Masri, M., Reuter, F.W. and Friedman, M. 1974. 'Binding of metal cations by natural substances'. *Journal of Applied Polymer Science* 18 (3): 675–681.

Mathews, C. and Beck, B.D.A. 1994. 'Evaluation of foliar diseases resistant ICRISAT groundnut varieties in KaNgwane South Africa'. *In* Ndunguru, B.J., Hilderbrand, G. L. and Subrahmanyam, P. (eds.), *Sustainable Groundnut Production in Southern and Eastern Africa: Proceedings of a Workshop*, 5–7 July 1994, Mbabane, Swaziland. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India.

Mathews, C., Lengwati, M.D., Smith, M.F. and Nigam, S.N. 2007. 'New groundnut varieties for smallholder farmers in Mpumalanga, South Africa'. *African Crop Science Conference Proceedings* 8: 251–257

Matumba, L., Monjerezi, M., Chirwa, E., Lakudzala, D. and Mumba, P. 2009. 'Natural occurrence of AFB_1 in maize and effect of traditional maize flour production on AFB_1 reduction in Malawi'. *African Journal of Food Science* 3 (12): 413–425.

Matumba, L., Monjerezi, M., Khonga, E.B. and Lakudzala, D.D. 2011. 'Aflatoxins in sorghum, sorghum malt and traditional opaque beer in southern Malawi'. *Food Control* 22 (2): 266–268.

Matumba, L., Van Poucke, C., Biswick, T., Monjerezi, M., Mwatseteza, J. and De Saeger, S. 2014. 'A limited survey of mycotoxins in traditional maize based opaque beers in Malawi'. *Food Control* 36 (1): 253–256.

Matumba, L., Van Poucke, C., Monjerezi, M., Ediage, E.N. and De Saeger, S. 2015. 'Concentrating aflatoxins on the domestic market through groundnut export: A focus on Malawian groundnut value and supply chain'. *Food Control* 51: 236–239.

Maxwell, P.D. 2001. 'Global cancer statistics in the year 2000'. *The Lancet Oncology* 2 (9): 533–543.

Maxwell, S.M., Apeagyei, F., De Vries, H.R., Mwanmut, D.D. and Hendrickse, R.G. 1989. 'Aflatoxins in breast milk, neonatal cord blood and sera of pregnant women'. *Toxin Reviews* 8 (1–2): 19–29.

Mazhour A, 1983. *Proceedings on the Expert Consultation on Planning the Development of Sundrying Techniques in Africa; Sechage Solaire au Maroc*, 12–16 December 1983. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Maziya-Dixon, B., Akinyele, I.O., Oguntona, E.B., Nokoe, S., Sanusi, R.A. and Harris. E. 2004. *Nigeria Food Consumption and Nutrition Survey: 2001–2003*. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Available at: http://www.iita.org/c/document_library/get_file?uuid=cd1e27d8-8721-489b-9a99-1f68a278d7cc&groupId=25357 [Accessed 1 October 2016].

Mbaye, A.A. 2005. *Sanitary and Phytosanitary Requirements and Developing-country Agro-food Exports: An Assessment of the Senegalese Groundnut Subsector*. The World Bank, Washington, DC, USA.

McCann, J. 2001. 'Maize and grace: History, corn, and Africa's new landscapes, 1500–1999'. *Comparative Studies in Society and History* 43: 246–272.

Mcmillian, W.W. 1987. 'Relation of insects to aflatoxin contamination in maize grown in the southeastern USA'. *In* Zuber, M.S., Lillehoj, E.B. and Renfro, B.L. (eds.), *Aflatoxin in Maize: A Proceedings of the Workshop*. International Maize and Wheat Improvement Centre (CIMMYT), Mexico City, Mexico.

Mcmillian, W.W., Widstrom, N.W., Wilson, D.M. and Evans, B.D. 1990. 'Annual contamination of *Heliothis zea* (Lepidoptera: Noctuidae) moths with *Aspergillus flavus* and incidence of aflatoxin contamination in preharvest corn in the Georgia coastal plain'. *Journal of Entomological Science* 25: 123–124.

Mehan, V.K. 1995. 'Practical approaches to the groundnut aflatoxin problem: research priorities'. *Aflatoxin Contamination Problems in Groundnut In West Africa: Proceedings of the First Working Group Meeting*, Food Crops Research Institute, 31 May–2 June 1995, Accra, Ghana. Arachide Infos no. 5. Centre de cooperation internationale en recherche agronomique pour le developpement (CIRAD), Montpellier, France.

Menkir, A., Brown, R.L., Bandyopadhyay, R. and Cleveland, T.E. 2008. 'Registration of six tropical maize germplasm lines with resistance to aflatoxin contamination'. *Journal of Plant Registrations* 2: 246–250.

Menya, W. 2011. 'Kenyan cereals maker recalls relief donation'. *Sunday Nation*, 9 October 2011.

Mensah, P., Yeboah-Manu, D., Owusu-Darko, K. and Ablordey, A. 2002. 'Street foods in Accra, Ghana: How safe are they?'. *Bulletin of the World Health Organization* 80 (7): 546–554.

Mestres, C., Bassa, S., Fagbohoun, E., Nago, M., Hell, K., Vernier, P. and Cardwell, K.F. 2004. 'Yam chip food sub-sector: hazardous practices and presence of aflatoxins in Benin'. *Journal of Stored Products Research* 40 (5): 575–585.

Miller, J.D. 1995. 'Mycotoxins'. *In* International Institute of Tropical Agriculture, *Mycotoxins in Food in Africa Workshop*, 6–10 November 1995, Benin. Available at: http://www.fao.org/in-action/inpho/library/detail/en/c/361/ [Accessed 1 October 2016].

Minister of Agriculture, Water and Forestry. 2014. Namibia Food Safety Policy. Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

Mintah, S. and Hunter, R.B. 1978. 'The incidence of aflatoxin found in groundnuts (*Arachis hypogea* L.) purchased from markets in and around Accra, Ghana. *Peanut Science* 5 (1): 13–16.

Misari, S.M., Boye-Goni, S. and Kaigama, B.K. 1988. 'Groundnut improvement, production, management, and utilization in Nigeria: Problems and prospects'. In International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (eds.), *First ICRISAT Regional Groundnut Meeting for West Africa*, 13– 16 September 1988, Niamey, Niger.

Mixon, A.C. 1986. 'Reducing *Aspergillus* species infection of peanut seed using resistant genotypes'. *Journal of Environmental Quality* 15 (2): 101–103.

Mngadi, P.T., Govinden, R. and Odhav, B. 2008. 'Co-occurring mycotoxins in animal feeds'. *African Journal of Biotechnology* 7 (13): 2239–2243.

Mofya-Mukuka, R. and Shipekesa, A.M. 2013. *Value Chain Analysis of the Groundnuts Sector in the Eastern Province of Zambia*. Working Paper No. 78. The Indaba Agricultural Policy Research Institute (IAPRI), Lusaka, Zambia.

Mohammed, A. and Chala, A. 2014. 'Incidence of *Aspergillus* contamination of groundnut (*Arachis hypogaea* L.) in eastern Ethiopia'. *African Journal of Microbiology Research* 8 (8): 759–765.

Mohammed-Alfa, M. and Tano-Debrah, K. 2011. *Safety of Animal Source Foods in Ghana – A Situational Analysis*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Mokoena, M.P., Chelule, P.K. and Gqaleni, N. 2006. 'The toxicity and decreased concentration of aflatoxin B_1 in natural lactic acid fermented maize meal'. *Journal of Applied Microbiology* 100(4): 773–7.

Monyo, E.S., Njoroge, S.M.C., Coe, R., Osiru, M., Madinda, F., Waliyar, F., Thakur, R.P., Chilunjika, T. and Anitha, S. 2012. 'Occurrence and distribution of aflatoxin contamination in groundnuts (*Arachis hypogaea* L) and population density of *Aflatoxigenic Aspergilli* in Malawi'. *Crop Protection* 42: 149–155.

Monyo, E.S., Waliyar, F., Osiru, M., Siambi, M. and Chinyamunyamu, B. 2010. *Assessing Occurrence and Distribution of Aflatoxins in Malawi*. *Project Final Report (Grant No. 08-598).* International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), National Smallholder Farmers' Association of Malawi (NASFAM) and The McKnight Foundation, USA.

Moore, G.G., Elliott, J.L., Singh, R., Horn, B.W., Dorner, J.W., Stone, E.A., Chulze, S.N., Barros, G.G., Naik, M.K., Wright, G.C., Hell, K. and Carbone, I. 2013. 'Sexuality generates diversity

in the aflatoxin gene cluster: Evidence on a global scale'. *PLoS Pathogens* 9(8): 1–12 (e1003574).

Morton, J. 2005. *A Darfur Compendium. A Review of Geographical, Historical and Economic Background to Development in the Region*. HTSPE, Hemel Hempstead, UK.

Moruke, E. 2015. *South African Food and Feed Safety Regulations: Where DAFF and DoH Differ*. Department of Agriculture, Forestry and Fisheries Directorate, Pretoria, South Africa.

Mphande, F.A., Siame, B.A. and Taylor, J.E. 2004. 'Fungi, aflatoxins, and cyclopiazonic acid associated with peanut retailing in Botswana'. *Journal of Food Protection* 67(1): 96–102.

Mulunda, M. and Mike, D., 2014. 'Occurrence of aflatoxin M 1 from rural subsistence and commercial farms from selected areas of South Africa'. *Food Control 39*: 92–96.

Munguambe, L. and Hendrickx, S.C.J. 2011. *Safety of Animal Source Foods in Mozambique – A Situational Analysis*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Munkvold, G.P. 2003. 'Cultural and genetic approaches to managing mycotoxins in maize'. *Annual Review of Phytopathology* 41: 99–116.

Munkvold, G.P., Hellmich, R.L. and Rice, L.G. 1999. 'Comparison of fumonisin concentrations in kernels of transgenic bt maize hybrids and nontransgenic hybrids'. *Plant Disease* 83 (2): 130–138.

Mupunga, I. 2013. *A Comparative Study of Natural Contamination with Aflatoxins and Fumonisins in Selected Food Commodities from Botswana and Zimbabwe*. Dissertation. University of South Africa. Available at: http://uir.unisa.ac.za/handle/10500/13339

Muraguri, N., Omulkoola, L.C., Kenji, G.M. and Condier, G.A. 1981. 'A survey of mycotoxins in human and animal foods: Part 1'. *East African Medical Journal* 58 (7): 484–488.

Mutasa, M.P. and Nyamandi, T. 1998. *Harmonisation of National/Regional Standards With Codex Standards*. *Report on Acceptances, Adoption and use of Codex Standards*. Codex Alimentarius Commission, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Mutasa, P.M. 2002. *Eisenhower Fellowship – Multination Programme 2002*. Standards Association of Zimbabwe, Harare, Zimbabwe.

Mutegi, C,K., Ngugi, H.K., Hendriks, S.L. and Jones, R.B. 2012. 'Factors associated with the incidence of *Aspergillus* section Flavi and aflatoxin contamination of peanuts in the Busia and Homa bay districts of western Kenya'. *Plant Pathology* 61 (6): 1143–1153.

Mutegi, C.K., Wagacha, J.M., Christie, M.E., Kimani, J. and Karanja, L. 2013a. 'Effect of storage conditions on quality and aflatoxin contamination of peanuts (*Arachis hypogaea* L.)'. *International Journal of AgriScience* 3 (10): 746–758.

Mutegi, C., Wagacha, M., Kimani, J., Otieno, G., Wanyama, R., Hell, K. and Christie, M.E. 2013b. 'Incidence of aflatoxin in peanuts (*Arachis hypogaea* Linnaeus) from markets in Western, Nyanza and Nairobi Provinces of Kenya and related market traits'. *Journal of Stored Products Research* 52: 118–127.

Muthomi, J.W., Njenga, L.N., Gathumbi, J.K. and Chemining'wa, G.N. 2009. 'The occurrence of aflatoxins in maize and distribution of mycotoxin-producing fungi in Eastern Kenya'. *Plant Pathology Journal (Faisalabad)* 8 (3): 113–119.

Mutiga, S.K., Hoffmann, V., Harvey, J., Milgroom, M.G. and Nelson, R. 2015. 'Assessment of aflatoxin and fumonisin contamination of maize in western Kenya'. *Phytopathology* 105 (9): 1250–61.

Mutungi, C., Lamuka, P., Arimi, S., Gathumbi, J. and Onyango, C. 2008. 'The fate of aflatoxins during processing of maize into muthokoi–a traditional Kenyan food'. *Food Control* 19 (7): 714–721.

Muture, B.N. and Ogana, G. 2005. 'Aflatoxin levels in maize and maize products during the 2004 food poisoning outbreak in Eastern Province of Kenya'. *East African Medical Journal* 82 (6): 275–279

Mwalwayo, D.S. and Thole, B. 2016. 'Prevalence of aflatoxin and fumonisins (B1 + B2) in maize consumed in rural Malawi'. *Toxicology Reports* 3: 173–179.

Mwenda, F.F. 1985. 'Groundnut breeding and improvement programs in Tanzania'. *In* International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (eds.) *Proceedings of the Regional Groundnut Workshop for Southern Africa*, 26–29 March 1984, Lilongwe, Malawi. ICRISAT, India.

Mwihia, J.T., Straetmans, M., Ibrahim, A., Njau, J., Muhenje, O., Guracha, A. and Lewis, L. 2008. 'Aflatoxin levels in locally grown maize from Makueni District, Kenya'. *East African Medical Journal* 85 (7): 311–317.

Nageswara Rao, R.C., Talwar, H.S. and Wright, G.C. 2001. 'Rapid assessment of specific leaf area and leaf N in peanut (*Arachis hypogaea*. L) using chlorophyll meter'. Journal of Agronomy and Crop Science 189: 175–182.

Nagy, A.H. and Youssef, Y.A. 1991. 'Occurrence of aflatoxins and aflatoxin-producing moulds in fresh and processed meat in Egypt'. *Food Additives & Contaminants* 8 (3): 321–331.

Naicker, D. and Botha, C.J. 2005. 'Aflatoxins in dog feed'. *Vet News: Newsletter of the South African Veterinary Association*. 26 September 2005.

Nakamya, R. 2008. *Studies on Fungi and Aflatoxins in Baby Foods Imported and Locally Manufactured in Uganda*. (Msc Thesis). Department of Botany, Makerere University, Kampala, Uganda.

Namulembwa, K. 2009. *Sihubira Multipurpose Cooperative Society (SIMUCO) Host Strategy, Uganda.* Cultivating New Frontiers in Agriculture (CNFA), Uganda.

Narayan, T., Belova, A. and Haskell, J. 2014. 'Aflatoxins: A negative nexus between agriculture, nutrition and health'. Paper prepared for presentation at the *Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting,* 27–29 July 2014, Minneapolis, USA.

Narrod, C., Wu, F., Tiongco, M., Mahuku, G., De Groote, H., Bettand, C. and Nzuku, S. 2011. *Evaluation of Risk Management Options to Reduce Aflatoxin in Maize Produced by Rural Farmers in Kenya*. Aflacontrol Working Paper. International Food Policy Research Institute (IFPRI), Washington, DC, USA.

Natamba, B.K., Wang, J.S., Young, S.L., Ghosh, S. and Griffiths, J.K., 2016. 'HIV-infected pregnant and lactating women have higher serum aflatoxin levels than HIV-uninfected women and aflatoxin levels are higher during early postpartum than during pregnancy among HIV-infected women'. *The FASEB Journal* 30(1): 668–5.

Nathaniels, N.Q. 2014. *Communicating Aflatoxin Messages: Recent Tanzanian Experience*. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/42258/ar_tanzania_aflatoxins.pdf?sequence=1&isAllowed=y

National Agency for Food and Drug Administration and Control (NAFDAC). 1996. *Pesticide Registrations*. *B 303*. NAFDAC, Abuja, Nigeria.

National Toxicology Program. 1980. *First Annual Report on Carcinogens July 1980*. US Department of Health and Human Services, New York, USA.

Nautiyal, P.C. 2002. *Groundnut: Post-harvest Operations*. Research Centre for Groundnut (ICAR), New Delhi, India.

Nautiyal, P.C., Bandyopadhyay, A. and Misra, R.C. 2004. 'Drying and storage methods to prolong seed viability of summer groundnut (*Arachis hypogaea*) in Orissa'. *Indian Journal of Agricultural Sciences* 74 (6): 316–320.

Ncube, E. 2008. *Mycotoxin Levels in Subsistence Farming Systems in South Africa*. Master of Science, Agriculture Thesis. University of Stellenbosch. Stellenbosch, South Africa.

Ncube, E., Flett, B.C., Waalwijk, C. and Viljoen, A. 2010. 'Occurrence of aflatoxins and aflatoxin-producing *Aspergillus* spp. associated with groundnut production in subsistence farming systems in South Africa'. *South African Journal of Plant and Soil* 27 (2): 195–198.

N'dede, C.B., Jolly, C.M., Vodouhe, S.D. and Jolly, P.E. 2012. 'Economic risks of aflatoxin contamination in marketing of peanut in Benin'. *Economics Research International* volume: page numbers.

Ndjeunga, J., Ntare, B.R., Ajeigbe, H., Echekwu, C.A., Ibro, A. and Amadou, A. 2013. *Adoption and Impacts of Modern Groundnut Varieties in Nigeria*. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India.

Ndung'u, J.W., Makokha, A.O., Onyango, C.A., Mutegi, C.K., Wagacha, J.M., Christie, M.E. and Wanjoya, A.K. 2013. 'Prevalence and potential for aflatoxin contamination in groundnuts and peanut butter from farmers and traders in Nairobi and Nyanza provinces of Kenya'. *Journal of Applied Biosciences* 65: 4922–4934.

Nduti, N., McMillan, A., Seney, S., Sumarah, M., Njeru, P., Mwaniki, M. and Reid, G., 2016. 'Investigating probiotic yoghurt to reduce an aflatoxin B1 biomarker among school children in eastern Kenya: Preliminary study'. *International Dairy Journal* 63*:* 124–129.

Nega, F., Mausch, K., Rao, K.P.C. and Legesse, G. 2015. *Scoping Study on Current Situation and Future Market Outlook of Groundnut in Ethiopia*. Socioeconomics Discussion Paper Series. Series paper number 38. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India.

Nelson, M.C., Margaret, M.W. and Lucy, K.M., 2016. 'Oil contents and aflatoxin levels in peanut varieties produced in Busia and Kisii Central Districts, Kenya'. *Tropical Medicine & Surgery* 4(204): 2.

Newberne, P.M. and Butler, W.H. 1969. 'Acute and chronic effects of aflatoxin on the liver of domestic and laboratory animals: a review'. *Cancer Research* 29: 236–250.

Ngindu, A., Kenya, P., Ocheng, D., Omondi, T., Ngare, W., Gatei, D. and Siongok, T.A. 1982. 'Outbreak of acute hepatitis caused by aflatoxin poisoning in Kenya'. *The Lancet* 319 (8285): 1346–1348.

Nguefack, J., Leth, V., Zollo, P.H. and Mathur, S.B. 2004. 'Evaluation of five essential oils from aromatic plants of Cameroon for controlling food spoilage and mycotoxin producing fungi'. *International Journal of Food Microbiology* 94: 329–334.

Nigam, S.N. and Lenne, J.M. 1996. 'Groundnut in ICRISAT programmes'. *Grain Legumes* 14: 25–27.

Nigam, S.N., Waliyar, F., Aruna, R., Reddy, S.V., Kumar, P.L., Craufurd, P.Q. and Diallo, A.T., Ntare, B.R. and Upadhyaya, H.D. 2009. 'Breeding peanut for resistance to aflatoxin contamination at ICRISAT'. *Peanut Science* 36 (1): 42–49.

Njapau, H., Muzungaile, E.M. and Changa, R.C. 1998. 'The effect of village processing techniques on the content of aflatoxins in corn and peanuts in Zambia'. *Journal of the Science of Food and Agriculture* 76 (3): 450–456.

Njobeh, P.B., Dutton, M.F., Koch, S.H., Chuturgoon, A.A., Stoev, S.D. and Mosonik, J.S. 2010. 'Simultaneous occurrence of mycotoxins in human food commodities from Cameroon'. *Mycotoxin Research* 26 (1): 47–57.

Njoroge, E. 2010. 'Kenya to mop up contaminated maize'. *Capital News* [online], Nairobi, Kenya. Available at: http://goo.gl/yyQ69O [Accessed 26 August 2013].

Nkwe, D.O., Taylor, J.E. and Siame, B.A. 2002. 'Fungi, aflatoxins, fumonisin B_1 and zearalenone contaminating sorghum-based traditional malt, wort and beer in Botswana'. *Mycopathologia* 160 (2): 177–86.

Noreddine, B. 2013. 'Traditional fermented foods of North African countries: Technology and food safety challenges with regard to microbiological risks. *Comprehensive Reviews in Food Science and Food Safety* 12 (1): 54–89.

Nout, M.J.R., Bouwmeester, H.M., Haaksma, J. and Van Dijk, H. 1993. 'Fungal growth in silages of sugarbeet press pulp and maize'. *Journal of Agricultural Science* 121: 323–326.

Ntare, B.R., Waliyar, F., Ramouch, M., Masters, E. and Ndjeunga, J. 2005. *Market Prospects for Groundnut in West Africa*. Common Fund for Commodities, Amsterdam, The Netherlands; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India.

Nuijten, E. 2010. 'Gender and management of crop diversity in The Gambia'. *Journal of Political Ecology* 17: 42–58.

Nwogu, E.O., and Nwankwo, F.I. 1979. 'A survey of the quality of yellow maize and white maize sold in Port Harcout markets'. *NSPRI Technical Report* 9: 83–85.

Nyambok, D., Oyla, J.R. and Braidotti, F. 2011. *Groundnut Agronomic Practices for Groundnut in Western Kenya. Training Manual for Trainers*. Comitato Europeo per la Formazione e l'Agricoltura Onlus (European Committee for Training and Agriculture) (CEFA), Place of publication.

Nyangaga, D.K. 2014. *Traders' Awareness and Level of Aflatoxins in Human Foods and Cattle Feeds in Selected Markets and Stores in Nairobi County, Kenya*. Ms Thesis. Department of Zoological Sciences, Kenyatta University, Nairobi, Kenya.

Nyinawabali, F. 2013. *A Survey of Fungi and Mycotoxins in Selected Food Commodities from Rwanda*. Doctoral Dissertation. Faculty of Health Sciences, University of Johannesburg, South Africa.

Nzeka, U.M. 2014. *Nigeria Grain and Feed Annual Report 2014*. GAIN Report Number: NI1204. United States Department of Agriculture Foreign Agricultural Service, Washington, DC, USA.

Nzima, W.M., Dzanja, J. and Kamwana, B. 2014. '*Structure, conduct and performance of groundnuts markets in Northern and Central Malawi: Case studies of Mzimba and Kasungu Districts'*. *International Journal of Business and Social Science* 5(6): 130–139.

O'Brian, G.R., Georgianna, D.R., Wilkinson, J.R., Yu, J., Abbas, H.K., Bhatnagar, D., Cleveland, T.E., Nierman, W. and Payne, G.A. 2007. 'The effect of elevated temperature on gene transcription and aflatoxin biosynthesis'. Mycologia 99(2): 232–9.

O'Neil, M.J., Smith, A. and Heckelman, P.E. 2001. *The Merck Index, An Encyclopaedia of Chemicals, Drugs, and Biologicals* (13th edn). Whitehouse Station, New Jersey, USA.

Obade, M.I., Andang'o, P., Obonyo, C. and Lusweti, F. 2015. 'Exposure of children 4 to 6 months of age to aflatoxin in Kisumu County, Kenya'. *African Journal of Food, Agriculture, Nutrition and Development* 15(2): 9949–9963.

Obasi, O.E., Ogbadu, G.H. and Ukoha, A.I. 1987. 'Aflatoxins in *burukutu* (millet beer)'. *Transactions of Royal Society of Tropical Medicine and Hygiene* 81: 879.

Obidoa, O. and Gugnani, H.C. 1990. 'Mycotoxins in Nigerian foods: Causes, consequences and remedial measures'. *In* Okoye, Z.S.C (eds.), *Mycotoxins Contaminating Foods and Foodstuffs in Nigeria. First National Workshop on Mycotoxins*, date of workshop. University of Jos, Jos, Nigeria.

Ochungo, P., Lindahl, J.F., Kayano, T., Sirma, A.J., Senerwa, D.M., Kiama, T.N. and Grace, D. 2016. 'Mapping aflatoxin risk from milk consumption using biophysical and socio-economic data: A case study of Kenya'. *African Journal of Food, Agriculture, Nutrition and Development* 16(3): 11066–11085.

Okano, K., Tomita, T., Ohzu, Y., Takai, M., Ose, A., Kotsuka, A., Ikeda, N., Sakata, J., Kumeda, Y., Nakamura, N. and Ichinoe, M. 2012. 'Aflatoxins B and G contamination and afatoxigenic fungi in nutmeg'. *Shokuhin Eiseigaku Zasshi* 53: 211–216.

Okeke, C.A., Ezekiel, C.N., Nwangburuka, C.C., Sulyok, M., Ezeamagu, C.O., Adeleke, R.A., Dike, S.K. and Krska, R. 2015. 'Bacterial diversity and mycotoxin reduction during maize fermentation (steeping) for *ogi* production'. *Frontiers in Microbiology* 6: 1402.

Okeke, K.S., Abdullahi, I.O., Makun, H.O. and Mailafiya, S.C. 2012. 'A preliminary survey of aflatoxin M_1 in dairy cattle products in Bida, Niger State, Nigeria'. *African Journal of Food Science and Technology* 3 (10): 273–6.

Okello, D.K., Biruma, M. and Deom, C.M. 2010. 'Overview of groundnuts research in Uganda: Past, present and future'. *African Journal of Biotechnology* 9 (39): 6448–6459.

Okello, D.K., Kaaya, A.N., Bisikwa, J., Were, M. and Oloka, H.K. 2010. *Management of Aflatoxins in Groundnuts. A Manual for Farmers, Processors, Traders and Consumers in Uganda*. National Agricultural Research Organisation in Collaboration with Makerere University, Uganda.

Okello, D.K., Monyo, E., Deom, C.M., Ininda, J. and Oloka, H.K. 2013. *Groundnuts Production Guide for Uganda: Recommended Practices for Farmers*. National Agricultural Research Organisation, Entebbe, Uganda.

Okello, D.K., Okori, P., Naveen, P., Boris, B.U., Deom, C.M., Ininda, J., Anguria, P., Biruma, M. and Asekenye, C. 2015. *Groundnut Seed Production Manual for Uganda*. National Agricultural Research Organization, Entebbe, Uganda.

Okobia, M.N. and Bunker, C.H. 2003. 'Molecular epidemiology of breast cancer: A review'. *African Journal of Reproductive Health* 7 (3): 17–28.

Okonkwo, P.O. and Nwokolo, C. 1978. 'Aflatoxin B_1: sample procedure to reduce levels in tropical foods'. *Nutrition Reports International* 17 (3): 387–395.

Okoth, S., Nyongesa, B., Ayugi, V., Kang'ethe, E., Korhonen, H. and Joutsjoki, V. 2012. 'Toxigenic potential of *Aspergillus* species occurring on maize kernels from two agro-ecological zones in Kenya'. *Toxins* 4 (11): 991–1007.

Okoth, S.A. and Kola, M.A. 2012. 'Market samples as a source of chronic aflatoxin exposure in Kenya'. *African Journal of Health Sciences* 20 (1): 56–61.

Okoth, S.A. and Ohingo, M. 2005. 'Dietary aflatoxin exposure and impaired growth in young children from Kisumu District, Kenya: Cross sectional study'. *African Journal of Health Sciences* 11 (1): 43–54.

Okoye, Z.S.C. and Ekpenyong, K.I. 1984. 'Aflatoxins B_1 in native millet beer brewed in Jos suburb'. *Transactions of Royal Society of Tropical Medicine and Hygiene* 78: 417–418.

Oloo, J. 2010. 'Food safety and quality management in Kenya: An overview of the roles played by various stakeholders'. *African Journal of Food Agriculture Nutrition and Development* 10 (11): 4379–4397.

Olorunmowaju, B.Y. 2012. *Fungi and Mycotoxins Contaminating Rice (*Oryza Sativa*) From Kaduna State*. (M. Tech Dissertation). Department of Biochemistry. Federal University of Technology, Minna, Nigeria.

Olsen, M., Johnsson, P., Mšller, T., Paladino, R. and Lindblad, M. 2008. '*Aspergillus nomius*, an important aflatoxin producer in Brazilnuts?'. *World Mycotoxin Journal* 1: 123–126.

Olusegun, A., Makun, H.A., Ogara, I.M., Edema, M., Idahor, K.O., Eshiett, M.E. and Oluwabamiwo, B.F. 2013. 'Fungal and mycotoxin contamination of Nigerian foods and feeds'. In Makun, H.A. (eds.), *Mycotoxin and Food Safety in Developing Countries*. Intech Open Science/Open Minds, Rijeka, Croatia.

Oluwafemi, F. and Da-Silva, FA. 2009. 'Removal of aflatoxins by viable and heat-killed *Lactobacillus* species isolated from fermented maize'. *Journal of Applied Biosciences* 16: 871–876.

Omar, W. 2015. *Preliminary investigation of aflatoxins in dietary ration of dairy cows in Khartoum North, Sudan*. Doctoral Dissertation. University of Khartoum, Khartoum, Sudan.

Omer, R.E., Bakker, M.I., Van't Veer, P., Hoogenboom, R.L., Polman, T.H., Alink, G.M., Idris, M.O., Kadar, A.M. and Kok, F.J. 1998. 'Aflatoxin and liver cancer in Sudan'. *Nutrition and Cancer* 32 (3): 174–180.

Omer, R.E., Verhoef, L., Van't Veer, P., Idris, M.O., Kadaru, A.M., Kampman, E., Bunschoten, A. and Kok, F.J. 2001. 'Peanut butter intake, $GSTM_1$ genotype and hepatocellular carcinoma: A case-control study in Sudan'. *Cancer Causes & Control* 12 (1): 23–32.

Omojokun, J. 2013. 'Regulation and enforcement of legislation on food safety in Nigeria'. *In* Makun, H.A. (eds.), *Mycotoxin and Food Safety in Developing Countries*. Intech Open Science/Open Minds, Rijeka, Croatia.

Onsongo, J. 2004. 'Outbreak of aflatoxin poisoning in Kenya'. *IDS Bulletin* 5: 3–4.

Onyemelukwe, G.C., Ogbadu, G.H. and Salifu, A. 1982. 'Aflatoxin B, G. and G_2 in primary liver cell carcinoma'. *Toxicology Letters* 10: 309–312.

Onyemelukwe, G.C., Ogoina, D., Ibiam, G.E. and Ogbadu, G.H. 2012. 'Aflatoxins in body fluids and food of Nigerian children with protein-energy malnutrition'. *African Journal of Food, Agriculture, Nutrition and Development* 12 (5): 6553–66.

Opadokun, J.S. 1992. 'Occurrence of aflatoxin in Nigeria food crops'. Paper presented at the *First National Workshop on Mycotoxins* 29 November 1990. University of Jos, Jos, Nigeria.

Orriss, G.D. 1999. 'Equivalence of food quality assurance systems'. *Food Control* 10: 255–260.

Ostadrahimi, A., Ashrafnejad, F., Kazemi, A., Sargheini, N., Mahdavi, R., Farshchian, M. and Mahluji, S. 2014. 'Aflatoxin in raw and salt-roasted nuts (pistachios, peanuts and walnuts) sold in markets of Tabriz, Iran'. *Jundishapur Journal of Microbiololgy* 7 (1): 1–5.

Ostrý, V., Malíř, F. and Pfohl-Leszkowicz, A., 2015. 'Comparative data concerning aflatoxin contents in Bt maize and non-Bt isogenic maize in relation to human and animal health: A review'. *Acta Veterinaria Brno* 84(1): 47–53.

Osuret, J., Musinguzi, G., Mukama, T., Halage, A.A., Natigo, A.K., Ssempebwa, J.C. and Wang, J.S. 2016. 'Aflatoxin contamination of selected staple foods sold for human consumption in Kampala markets, Uganda'. *Journal of Biological Sciences* 16(1): 44.

Otsuki, T., Wilson, J. and Sewadeh, M. 2001. 'Saving two in a billion: Quantifying the trade effect of European Food Safety Standards on African Exports'. *Food Policy* 26 (5): 495–514.

Otsuki, T., Wilson, J. and Sewadeh, M. 2001. 'What price precaution? European harmonization of aflatoxin regulations and African groundnut export'. *European Review of Agricultural Economics* 28 (2): 263–283.

Oueslati, S., Blesa, J., Moltó, J.C., Ghorbel, A. and Mañes, J. 2014. 'Presence of mycotoxins in sorghum and intake estimation in Tunisia'. *Food Additives & Contaminants: Part A* 31 (2): 307–18.

Oyejide, A., Tewe, O.O. and Okosum, S.E. 1987. 'Prevalence of aflatoxin B_1 in commercial poultry rations in Nigeria'. *Beitr Trop Landwirtsch Veterinarmed* 25 (3): 337–41.

Oyelami, O.A., Maxwell, S.M. and Adeoba, E. 1996. 'Aflatoxins and ochratoxin A in the weaning food of Nigerian children'. *Annals of Tropical Paediatrics* 16 (2): 137–140.

Oyelami, O.A., Maxwell, S.M., Adelusola, K.A., Aladekoma, T.A. and Oyelese, A.O. 1997. 'Aflatoxins in the lungs of children with kwashiorkor and children with miscellaneous diseases in Nigeria'. *Journal of Toxicology and Environmental Health* 51 (6): 623–628.

Oyelami, O.A., Maxwell, S.M., Adelusola, K.A., Aladekoma, T.A. and Oyelese, A.O. 1998. 'Aflatoxins in autopsy kidney specimens from children in Nigeria'. *Journal of Toxicology and Environmental Health A*55: 317–23.

Oyero, O.G. and Oyefolu, A.B. 2010. 'Natural occurrence of aflatoxin residues in fresh and sun-dried meat in Nigeria'. *Pan African Medical Journal* 7: 1.

Ozimati, A.A., Rubaihayo, P.R., Gibson, P., Edema, R., Kayondo, I.S., Ntare, B.R. and Okello, D.K. 2014. 'Inheritance of resistance to kernel infection by *Aspergillus flavus* and aflatoxin accumulation in groundnut'. African Journal of Crop Science 2 (1): 51–59.

Palliyaguru, D.L. and Wu, F. 2014. 'The global geographical overlap of aflatoxin and hepatitis C: controlling risk factors for liver cancer worldwide'. *Food Additives & Contaminants Part A Chemistry Analysis Control Exposure Risk Assessment* 30(3): 534–540.

Pande, S., Bandyopadhyay, R., Blümmel, M., Narayana Rao, J., Thomas, D. and Navi, S.S. 2003. 'Disease management factors influencing yield and quality of sorghum and groundnut crop residues'. Field Crops Resarch 84 (1–2): 89–103.

Papa, K.E. 1986. 'Heterokaryon incompatibility in *Aspergillus* flavus'. *Mycologia* 78: 98–101.

Park, D.L. 2002. 'Effect of processing on aflatoxin'. *Advances in Experimental Medicine and Biology* 504: 173–179.

Partnership for Aflatoxin Control in Africa (PACA). 2013. Aflatoxin Impacts and Potential Solutions in Agriculture, Trade, and Health. A Background Paper for the PACA Strategy Development–Stakeholder Consultation Workshop. PACA, Addis Ababa, Ethiopia.

Pascale, M. and Visconti, A. 2008. 'Overview of detection methods for mycotoxins'. *In* Leslie, J.F. and Visconti, A. (eds.) *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*. Cromwell Press, Trowbridge, Wiltshire, UK.

Pazderka, C. and Emmott, A. 2010. *Chatham House Procurement for Development Forum: Groundnuts Case Study*. Chatham House, London, UK.

Pearson, T.C., Wicklow, D.T. and Pasikatan, M.C. 2004. 'Reduction of aflatoxin and fumonisin contamination in yellow corn by high-speed dual-wavelength sorting'. *Cereal Chemistry* 81 (4): 490–498.

Peers, F. 1965. Summary of the work done at-Vom (Northern Nigeria) on aflatoxin levels in grondnut flour and Arlac. Nutr. Docum. Presented at Aflatoxin/8. WHO/FAO/UNICEP—PAG 1965 Meeting, Rome.

Peers, F.G. and Linsell, C.A. 1973. 'Dietary aflatoxins and liver cancer – A population based study in Kenya'. *British Journal of Cancer* 27(6): 473–484.

Peterson, S.W., Ito, Y., Horn, B.W. and Goto, T. 2001. '*Aspergillus bombycis*, a new aflatoxigenic species and genetic variation in its sibling species, *A. nomius'. Mycologia* 93: 689–703.

Phillips, T.D., Afriyie-Gyawu, E., Williams, J., Huebner, H., Ankrah, N.A., Ofori-Adjei, D. and Wang, J.S. 2008. 'Reducing human exposure to aflatoxin through the use of clay: A review'. *Food additives & Contaminants* 25 (2): 134–145.

Phillips, T.D., Lemke, S.L. and Grant, P.G. 2002. 'Characterization of clay-based enterosorbents for the prevention of aflatoxicosis'. *Mycotoxins and Food Safety* 504: 157–171.

Piekkola, S., Turner, P.C., Abdel-Hamid, M., Ezzat, S., El-Daly, M., El-Kafrawy, S., Savchenko, E., Poussa, T., Woo, J.C., Mykkänen, H. and El-Nezami, H. 2012. 'Characterisation of aflatoxin and deoxynivalenol exposure among pregnant Egyptian women'. *Food Additives & Contaminants Part A Chemistry Analysis Control Exposure and Risk Assessment* 29: 962–71.

Pildain, M.B., Frisvad, J.C., Vaamonde, G., Cabral, D., Varga, J. and Samson, R.A. 2008. 'Two novel aflatoxin-producing *Aspergillus* species from Argentinean peanuts'. *International Journal of Systematic and Evolutionary Microbiology* 58 (3): 725–735.

Pinstup-Andersen, P. 2000. 'Rich and poor country perspective on biotechnology'. Paper presented at the preconference workshop jointed convened by the Australian Agricultural Resource Economic Society and International Food Policy Research Institute, *Agricultural Biotechnology: Markets and Policies in an International Setting*, 22 January 2001, Adeleide, Australia.

Pitt, J.I. 1989. 'Field studies on *Aspergillus* flavus and aflatoxins in Australian groundnuts'. *In*: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). *International Workshop on Aflatoxin Contamination of Groundnut, 6*–9 October 1987, *Patancheru, India.* ICRISAT, Hyderabad, India.

Pitt, J.I. 1995. 'Under what conditions are mycotoxins produced? *Aspergillus* species'. *Australian Mycotoxin Newsletter* 6 (4): 1–2.

Polixeni, V. and Panagiota, M. 2008. 'Aflatoxin B1 and ochratoxin A in breakfast cereals from Athens market: Occurrence and risk assessment'. Lab of Food Chemistry, Department of Chemistry, *University of Athens*, Athens, Greece.

Pollet, A., Declert, C., Wiegandt, W., Harkema, J. and de Lisdonk, E. 1989. 'Traditional groundnut storage and aflatoxin problems in Côte d'Ivoire: Ecological approaches'. In *Proceedings of the International Workshop on Aflatoxin Contamination of Groundnut,* 06–09 October 1987, ICRISAT Center, Patancheru India.

Polychronaki, N., Turner, C.P., Mykkänen, H., Gong, Y., Amra, H., Abdel-Wahhab, M. and El-Nezami, H. 2006. 'Determinants of aflatoxin M_1 in breast milk in a selected group of Egyptian mothers'. *Food Additives & Contaminants* 23 (7): 700–708.

Polychronaki, N., West, R.M., Turner, P.C., Amra, H., Abdel-Wahhab, M., Mykkänen, H. and El-Nezami, H. 2007. 'A longitudinal assessment of aflatoxin M_1 excretion in breast milk of selected Egyptian mothers'. *Food and Chemical Toxicology* 45 (7): 1210–1215.

Polychronaki, N., Wild, C.P., Mykkänen, H., Amra, H., Abdel-Wahhab, M., Sylla, A. and Turner, P.C. 2008. 'Urinary biomarkers of aflatoxin exposure in young children from Egypt and Guinea'. *Food and Chemical Toxicology* 46 (2): 519–526.

Probst, C., Bandyopadhyay, R. and Cotty, P. 2014. 'Diversity of aflatoxin-producing fungi and their impact on food safety in sub-Saharan Africa'. *International Journal of Food Microbiology* 174: 113–122.

Probst C., Callicott, K.A. and Cotty, P.J. 2012. 'Deadly strains of Kenyan *Aspergillus* are distinct from other aflatoxin producers'. *European Journal of Plant Pathology* 132: 419–429.

Probst, C., Njapau, H. and Cotty, P. 2007. 'Outbreak of an acute aflatoxicosis in Kenya: Identification of the causal agent'. *Applied and Environmental Microbiology* 73 (8): 2762–2764.

PROMEC Unit. 2001. *Aflatoxin in Peanut Butter.* MRC Policy Brief No. 3. Medical Research Council, Tygerberg, South Africa.

Ramjee, G., Berjak, P., Adhikari, M. and Dutton, M.F. 1991. 'Aflatoxins and kwashiorkor in Durban, South Africa'. *Annals of Tropical Paediatrics* 12 (3): 241–247.

Raney, K.D., Meyer, D.J., Ketterer, B., Harris, T.M. and Guengerich, F.P. 1992. 'Glutathione conjugation of aflatoxin B_1 exo-and endo-epoxides by rat and human glutathione S-transferases'. *Chemical Research in Toxicology* 5 (4): 470–478.

Ranga Rao, G.V., Rameshwar Rao, V. and Nigam, S.N. 2010. *Postharvest Insect Pests of Groundnut and their Management.* Information Bulletin No. 84. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India.

Rank, C., Nielsen, K.F., Larsen, T.O., Varga, J., Samson, R.A. and Frisvad, J.C. 2011. 'Distribution of sterigmatocystin in filamentous fungi'. *Fungal Biology* 115: 406–420.

Rava, E. 1996. 'Mycotoxins in maize products of the 1994/95 marketing season'. *Mycotoxin Research* 12 (1): 25–30.

Rava, E., Viljoen, J.H., Kallmeyer, H. and De Jager, A. 1996. 'Fungi and mycotoxins in South African maize of the 1993 crop'. *Mycotoxin Research* 12 (1): 15–24.

Reddy, E.C.S., Sudhakar, C. and Eswara Reddy, N.P. 2011. 'Aflatoxin contamination in groundnut induced by *Aspergillus flavus* type fungi: A critical review'. International Journal of Applied Biology and Pharmaceutical Technology 2 (2): 180–192.

Reddy, S.V., Mayi, D.K., Reddy, M.U., Thirumala-Devi, K. and Reddy, D.V. 2001. 'Aflatoxin B_1 in different grades of chillies (*Capsicum annum* L.) in India as determined by indirect competitive-ELISA'. *Food Additives & Contaminants* 18: 553–558.

Reece, J.D., Dalohoun, D.N., Drammeh, E., van Mele, P. and Bah, S. 2011. The Gambia: Capturing the Media. *In* Van Mele, P., Bently, J.W. and Guéi, R.G. *African Seed Enterprises: Sowing the Seeds of Food Security*. CABI Publications, Wallingford, UK.

Reyers, F. and Miller, D.B. 2000. 'Canine aflatoxicosis'. Paper presented at the *Congress of the South African Veterinary Association*, 20–22 September 2000, Durban, South Africa.

Rheeder, J.P., Sydenham, E.W., Marasas, W.F.O., Thiel, P.G., Shephard, G.S., Schlechter, M. and Viljoen, J.H. 1994. 'Ear-rot fungi and mycotoxins in South African corn of the 1989 crop exported to Taiwan'. *Mycopathologia* 127 (1): 35–41.

Rheeder, J.P., Sydenham, E.W., Marasas, W.F.O., Thiel, P.G., Shephard, G.S., Schlechter, M. and Viljoen, J.H. 1995. 'Fungal infestation and mycotoxin contamination of South African commercial maize harvested in 1989 and 1990'. *South African Journal of Science* 91 (3): 127–131.

Ribeiro, J., Cavaglieri, L., Fraga, M., Direito, G., Dalcero, A. and Rosa, C. 2006. 'Influence of water activity, temperature and time on mycotoxins production on barley rootlets'. *Letters in Applied Microbiology* 42: 179–184.

Rios, L.B.D. and Jaffee, S. 2008. *Barrier, Catalyst or Distraction? Standards, Competitiveness and Africa's Groundnut Exports to Europe*. World Bank Agriculture and Rural Development Discussion Paper 39. World Bank, Washington, DC, USA.

Rodrigues, I., Handl, J. and Binder, E.M. 2011. 'Mycotoxin occurrence in commodities, feeds and feed ingredients sourced in the Middle East and Africa'. *Food Additives & Contaminants Part B* 4(3): 168–179.

Ross, R.K., Yu, M.C., Henderson, B.E., Yuan, J.M., Qian, G.S., Tu, J.T. and Groopman, J.D. 1992. 'Urinary aflatoxin biomarkers and risk of hepatocellular carcinoma'. *The Lancet* 339 (8799): 943–946.

Rushunju, G.B., Laswai, H.S., Ngowi, H.A. and Katalambula, L.K. 2013. 'Aflatoxin contamination of locally processed cereal-based complementary foods in Tanzania'. Tanzania Veterinary Journal 28: 56–60.

Sabbioni, G., Skipper, P.L., Büchi, G. and Tannenbaum, S.R. 1987. 'Isolation and characterization of the major serum albumin adduct formed by aflatoxin B_1 in vivo in rats'. *Carcinogenesis* 8 (6): 819–824.

Saeed, M.A.I. 2015. *The Incidence of Aflatoxin in Freshly Cut Sorghum Varieties Grown in The Sudan*. Doctoral Dissertation. University of Khartoum, Khartoum, Sudan.

Sahel and West Africa Club. 2006. Food Security and Cross Border Trade in Kano-Katsina-Maradi K^2M Corridor. West African Borders and Integration (WABI) Initiative, Dakar, Senegal.

Sangare-Tigori, B., Moukha, S., Kouadio, H.J., Betbeder, A.M., Dano, D.S. and Creppy, E.E. 2006. 'Co-occurrence of aflatoxin B_1, fumonisin B_1, ochratoxin A and zearalenone in cereals and peanuts from Côte d'Ivoire'. *Food Additives & Contaminants* 23 (10): 1000–1007.

Savage, G.P. and Keenan, J.I. 1994. 'The composition and nutritive value of groundnut kernels'. *In* Samrtt, J. (eds.), *A Scientific Basis for Improvement*. Chapman and Hall, St Edmundsbury Press, UK.

Schoental, R, 1967. 'Aflatoxins'. *Annual Review of Pharmacology* 7 (1): 343–356.

Schuda, P.F. 1980. 'Aflatoxin chemistry and syntheses'. *Syntheses of Natural Products, Topics in Current Chemistry* 91: 75–111.

Sebunya, T.K. and Yourtee, D.M. 1990. 'Aflatoxigenic *Aspergilli* in foods and feeds in Uganda'. *Journal of Food Quality* 13 (2): 97–107.

Senghor, A.L. 2015. *Atelier Régional sue la Revalorisation de la Chaine de Valeur de l'Arachide à Travers la Réduction de l'Aflatoxine: Le Problème de l'Aflatoxin sur Arachide en Afrique de l'Ouest*. Available at: http://aflatoxinpartnership.org/uploads/2.2%20-

%20The%20aflatoxin%20challenge%20to%20the%20GN%20sector%20in%20West%20Africa.pdf

Serck-Hanssen, A. 1970. 'Aflatoxin-induced fatal hepatitis'. *Archives of Environmental Health: An International Journal* 20 (6): 729–731.

Setamou, M., Cardwell, K., Schulthess, F. and Hell, K. 1997. '*Aspergillus flavus* infection and aflatoxin contamination of preharvest maize in Benin'. *Plant Disease* 81 (11): 1323–1327.

Sétamou, M., Cardwell, K.F., Schulthess, F. and Hell, K. 1998. 'Effect of insect damage to maize ears, with special reference to *Mussidia nigrivenella* (Lepidoptera: Pyralidae), on *Aspergillus flavus* (Deuteromycetes: Monoliales) infection and aflatoxin production in maize before harvest in the Republic of Benin'. *Journal of Economic Entomology* 91: 433–438.

Shephard, G. S. 2004. 'Aflatoxin and food safety: Recent African perspective'. *Jounal of Toxicology: Toxin Reviews* 22(2–3): 267–286.

Shephard, G.S., Burger, H.M., Gambacorta, L., Gong, Y.Y., Krska, R., Rheeder, J.P., Solfrizzo, M., Srey, C., Sulyok, M., Visconti, A., Warth, B. and Westhuizen, L. 2013. 'Multiple mycotoxin exposure determined by urinary biomarkers in rural subsistence farmers in the former Transkei, South Africa'. *Food and Chemical Toxicology* 62: 217–225.

Shephard, G.S., Berthiller, F., Burdaspal, P.A., Crews, C., Jonker, M.A., Krska, R., Lattanzio, V.M.T., MacDonald, S., Malon, R.J., Maragos, C., Sabino, M., Solfrizzo, M., Van Egmond, H.P. and Whitaker, T.B. 2011. 'Developments in mycotoxin analysis: An update for 2011–2012'. *World Mycotoxin Journal* 6 (1): 3–30.

Shephard, G.S., Marasas, W.F.O., Burger, H.-M., Somdyala, N.I.M., Rheeder, J.P., Van der Westhuizen, L., Gatyeni, P. and Van Schalkwyk, D.J. 2007. 'Exposure assessment for fumonisins in the former Transkei region of South Africa'. *Food Additives and Contaminants* 24: 621–629.

Shipekesa, A. and Jayne, T.S. 2011. *Why Are Zambian Farmers not Harvesting All Their Maize?* Food Security Research Project Policy Synthesis No. 45. Ministry of Agriculture and Cooperatives, Lusaka, Zambia.

Shipekesa, A. and Jayne, T.S. 2012. *Gender Control and Labour Input: Who Controls the Proceeds from Staple Crop Production among Zambian Farmers?* Indaba Agricultural Policy Research Institute (IAPRI) Working Paper No. 68. IAPRI, Lusaka, Zambia.

Shirima, C.P., Kimanya, M.E., Kinabo, J.L., Routledge, M.N., Srey, C., Wild, C.P., and Gong, Y.Y. 2013. 'Dietary exposure to aflatoxin and fumonisin among Tanzanian children as determined using biomarkers of exposure'. *Molecular Nutrition & Food Research* 57 (10): 1874–1881.

Shirima, C.P., Kimanya, M.E., Routledge, M.N., Srey, C., Kinabo, J.L., Humpf, H.U. and Gong, Y.Y. 2015. 'A prospective study of growth and biomarkers of exposure to aflatoxin and fumonisin during early childhood in Tanzania'. *Environmental Health Perspectives* 123(2): 173.

Shoko, R.R. 2014. *Estimating the Supply Response of Maize in South Africa*. Master of Science in Agriculture (Agricultural Economics) Thesis. Faculty of Science and Agriculture, University of Limpopo, South Africa.

Shuaib, F.M., Jolly, P.E., Ehiri, J.E., Jiang, Y., Ellis, W.O., Stiles, J.K. and Williams, J.H. 2010. 'Association between anemia and aflatoxin B1 biomarker levels among pregnant women in Kumasi, Ghana'. *The American Journal of Tropical Medicine and Hygiene* 83 (5): 1077–1083.

Siame, B.A., Mpuchane, S.F., Gashe, B.A., Allotey, J. and Teffera, G. 1998. 'Occurrence of aflatoxins, fumonisin B_1, and zearalenone in foods and feeds in Botswana'. *Journal of Food Protection* 61 (12): 1670–1673.

Sid, M.M., Haddon, W.F., Lundin, R.E. and Hsieh, D.P.H. 1974. 'Aflatoxin Q_1. Newly identified major metabolite of aflatoxin B_1 in monkey liver'. *Journal of Agricultural and Food Chemistry* 22: 512–515.

Sirma, A., Senerwa, D., Lindahl, J., Makita, K., Kang'ethe, E., Grace, D. 2014. *Aflatoxin M_1 Survey In Dairy Households In Kenya*. Poster prepared for the FoodAfrica Midterm Seminar, 16 June 2014, Helsinki, Finland.

Sirma, A.J., Ouko, E.O., Murithi, G., Mburugu, C., Mapenay, I., Ombui, J.N., Kang'ethe, E.K. and Korhonen, H. 2015. 'Prevalence of aflatoxin contamination in cereals from Nandi County, Kenya'. *International Journal of Agricultural Sciences and Veterinary Medicine* 3(3): 55–63.

Sitko, N.J, Chapoto, A., Kabwe, S. Tembo, S., Hichaambwa, M., Lubinda, R., Chiwawa, H., Mataa, M., Heck, S. and Nthani, D. 2011. *Technical Compendium: Descriptive Agricultural Statistics and Analysis for Zambia in Support of the USAID Mission's Feed the Future Strategic Review*. Food Security Research Project (FSRP) Working Paper No. 52. FSRP, Lusaka, Zambia.

Skipper, P.L., Hutchins, D.H., Turesky, R.J., Sabbioni, G. and Tannenbaum, S.R. 1985. 'Carcinogen binding to serum-albumin'. *Proceedings of the American Association for Cancer Research* 26 (March): 90–90. American Association for Cancer Research, Philadelphia, USA.

Smart, J. 1994. 'The groundnut in farming system and the rural economy – A global view'. *In* Smart, J. (eds.), *The Groundnut Crop. A Scientific Basis for Improvement*. Chapman and Hall, London, UK.

Smart, M.G., Shotwell, O.L. and Caldwell, R.W. 1994. 'Pathogenesis in *Aspergillus* ear rot of maize: Aflatoxin B1 levels in grains around wound inoculation sites'. *Phytopatology* 80: 1283–1286.

Smith, A.F. 2002. *Peanuts: The Illustrious History of the Goober Pea*. University of Illinois Press, Chicago, USA.

Smith, D.H., Crossby, F.L. and Ethredge, W.J. 1974. 'Disease forecasting facilitates chemical control of Cercospora leaf spot of peanuts'. *Plant Disease Reporter* 58: 666–668.

Soares, C., Rodrigues, P., Peterson, S.W., Lima, N., Venâncio, A. 2012. 'Three new species of *Aspergillus* section Flavi isolated from almonds and maize in Portugal'. *Mycologia* 104 (3): 682–697.

Soler, T., Hoogenboom, G., Olatinwo, R., Diarra, B., Waliyar, F. and Traore, S. 2010. 'Peanut contamination by *Aspergillus flavus* and aflatoxin B_1 in granaries of villages and markets of Mali, West Africa'. *Journal of Food, Agriculture & Environment* 8 (2): 195–203.

Song, D.K. and Karr, A.L. 1993. 'Soybean phytoalexin, glyceollin, prevents accumulation of aflatoxin B1 in cultures of *Aspergillus flavus*'. *Journal of Chemical Ecology* 19 (6): 1183–1194.

Speijers, G.J.A. and Speijers, M.H.M. 2004. 'Combined toxic effects of mycotoxins'. *Toxicology Letters* 153 (1): 91–98.

Squire, R.A. 1981. 'Rating animal carcinogens: A proposed regulatory approach'. *Science* 214: 877–880.

Sripathomswat, N. and Thasnakorn, P. 1981. 'Survey of aflatoxin producing fungi in certain fermented foods and beverages in Thailand'. *Mycopathologia* 73: 83–88.

Srivastava, V.P., Bu-Abbas, A., Alaa-Basuny, Al-Johar, W., Al-Mufti, S., Siddiqui, M.K. 2001. 'Aflatoxin M_1 contamination in commercial samples of milk and dairy products in Kuwait'. *Food Additives & Contaminants*18: 993–997.

Ssebukyu, E.K. 2002. *Fungi and Aflatoxins in Maize in Uganda*. MSc Thesis. Department of Botany, Makerere University, Kampala, Uganda.

Staatskoerant. 2008. *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (act no. 36 of 1947). Publication of South African Policy on Animal Feeds*. Notice 511 of 2008. Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa.

Stroka, J. and Anklam, E. 2002. 'New strategies for the screening and determination of aflatoxins and the detection of aflatoxin-producing moulds in food and feed'. *Trends in Analytical Chemistry* 21: 90–95.

Strosnider, H., Azziz-Baumgartner, E., Banziger, M., Bhat, R.V., Breiman, R., Brune, M.N., DeCock, K., Dilley, A., Groopman, J., Hell, K., Henry, S.H., Jeffers, D., Jolly, C., Jolly, P., Kibata, G.N., Lewis, L., Liu, X., Luber, G., McCoy, L., Mensah, P., Miraglia, M., Misore, A., Njapau, H., Ong, C.N., Onsongo, M.T., Page, S.W., Park, D., Patel, M., Phillips, T., Pineiro, M., Pronczuk, J., Rogers, H.S., Rubin, C., Sabino, M., Schaafsma, A., Shephard, G., Stroka, J., Wild, C., Williams, J.T. and Wilson, D. 2006. 'Workgroup report: Public health strategies for reducing aflatoxin exposure in developing countries'. *Environmental Health Perspectives* 114: 1989–1903.

Swanevelder, C.J. 1994. 'Achievements and future prospects of groundnut production and research in South Africa'. *In* Ndunguru, B.J., Hilderbrand, G. L. and Subrahmanyam, P. (eds.), *Sustainable Groundnut Production in Southern and Eastern Africa: Proceedings of a Workshop*, 5–7 July 1994, Mbabane, Swaziland. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India.

Sylla, F. 2010. *Revitalization of the Groundnut Sector in West Africa (Gambia, Guinea Bissau and Senegal)*. United States Department of Agriculture Foreign Agricultural Service, Washington, DC, USA.

Tannenbaum, S.R. and Skipper, P.L. 1984. 'Biological aspects to the evaluation of risk: dosimetry of carcinogens in man'. *Fundamental and Applied Toxicology* 4 (3): S367–S373.

Tchana, A.N., Moundipa, P.F. and Tchouanguep, F. M. 2010. 'Aflatoxin contamination in food and body fluids in relation to malnutrition and cancer status in Cameroon'. *International Journal of Environmental Research and Public Health* 7 (1): 178–188.

Tefera, T. and Tana, T. 2002. 'Agronomic performance of sorghum and groundnut cultivations in sole and intercrop cultivation under semi-arid conditions'. *Journal of Agronomy and Crop Science* 188: 212–218.

Temesgen, M. and Abdisa, M. 2015. 'Food standards, food law and regulation system in Ethiopia: A review'. *Public Policy and Administration Research* 5 (3): 58–72.

Thorne, P.J., Thornton, P.K., Kruska, R.L., Reynolds, L., Waddington, S.R., Rutherford, A.S. and Odero, A.N. 2002. *Maize as Food, Feed and Fertiliser in Intensifying Crop-livestock systems in East and Southern Africa: An Ex Ante Impact Assessment of Technology Interventions to Improve Smallholder Welfare*. International Livestock Research Institute (ILRI) Impact Assessment Series 11. ILRI, Nairobi, Kenya.

Thuvander, A., Moller, T., Barbierri, H.E., Jansson, A., Salomonsson, A.C. and Olsen, M. 2001. 'Dietary intake of some important mycotoxins by the Swedish population'. *Food Additives & Contaminants* 18: 696–706.

Tijani, A.S. 2005. *Survey of Fungi, Aflatoxins and Zearalenone Contamination of Maize in Niger State*. M.Sc Thesis. Department of Biochemistry, Federal University of Technology Minna, Ihiagwa, Nigeria.

Tiongco, M., De groote, H., Saak, A., Narrod, C. and Scott, R. 2011a. *Estimating Producers Demand for Reducing Technologies of Aflatoxin Contamination on Maize in Kenya*. Aflacontrol Working Paper. International Food Policy Research Institute (IFPRI), Washington, DC, USA.

Tiongco, M., Ndjeunga, J., De groote, H., Narrod, C., Saak, A. and Scott, R. 2011b. *Estimating Producers' Demand for Risk Reducing Technologies of Aflatoxin Contamination on Groundnuts in Mali*. Aflacontrol Working Paper. International Food Policy Research Institute (IFPRI), Washington, DC, USA.

Tsuboi, S., Nakagawa, T., Tomita, M., Seo, T., Ono, H., Kawamura, K. and Iwamura, N. 1984. 'Detection of aflatoxin B_1 in serum samples of male Japanese subjects by radioimmunoassay and high-performance liquid chromatography'. *Cancer Research* 44 (3): 1231–1234.

Tubajika, K.M. and Damann, K.E. 2001. 'Sources of resistance to aflatoxin production in maize'. *Journal of Agricultural and Food Chemistry* 49 (5): 2652–2656.

Tulasne, J.J. 2002. 'The regional network of food testing laboratories in Western and Central Africa: Support for a quality assurance approach'. *In* Hanak, E., Boutrif E., Fabre, P. and Pineiro, M. (eds.), *Food Safety Management in Developing Countries*. Food and Agriculture Organization of the United Nations (FAO) and CIRAD, Montpellier, France. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.201.9764&rep=rep1&type=pdf

Turner, P.C., Collinson, A.C., Cheung, Y.B., Gong, Y., Hall, A.J., Prentice, A.M. and Wild, C.P. 2007. 'Aflatoxin exposure in utero causes growth faltering in Gambian infants' *International Journal of Epidemiology* 36 (5): 1119–25.

Turner, P.C., Mendy, M., Whittle, H., Fortuin, M., Hall, A.J. and Wild, C.P. 2000. 'Hepatitis B infection and aflatoxin biomarker levels in Gambian children'. *Tropical Medicine and International Health* 5: 837–841.

Turner, P.C., Moore, S.E., Hall, A.J., Prentice, A.M. and Wild, C.P. 2003. 'Modification of immune function through exposure to dietary aflatoxin in Gambian children'. *Environmental Health Perspectives* 111 (2): 217–220.

Turner, P.C., Sylla, A., Gong, Y.Y., Diallo, M.S., Sutcliffe, A.E., Hall, A.J. and Wild, C.P. 2005. 'Reduction in exposure to carcinogenic aflatoxins by post harvest intervention measures in west Africa a community-based intervention study'. *Lancet* 365 (9475): 1950–1956.

Ubwa, S.T., Abah, J., Atu, B.O., Tyohemba, R.L. and Yande, J.T. 2014. 'Assessment of total aflatoxins level of two major nuts consumed in Makurdi Benue State, Nigeria'. *International Journal of Nutrition and Food Sciences* 3 (5): 397–403.

Udoh, J.M., Cardwell, K.F. and Ikotun, T. 2000. 'Storage structures and aflatoxin content of maize in five agroecological zones of Nigeria'. *Journal of Stored Products Research* 36**:** 182–201.

United Nations Industrial Development Organization (UNIDO). 2010. *Capacity Building for Aflatoxin Management in Groundnuts in Malawi: Final Report February 2009-December 2010*. UNIDO, Vienna, Austria.

United Nations Industrial Development Organization (UNIDO). 2012. *Independent Evaluation of the UNIDO Project: Capacity Building for Aflatoxin Management and Control in Groundnuts in Malawi*. UNIDO, Vienna, Austria.

United States Agency for International Development (USAID). 2010. *Staple Foods Value Chain Analysis. Country Report: Tanzania*. USAID, Washington, DC, USA.

Unnevehr, L.J. 2000. 'Food safety issues and fresh food product exports from LDCs'. *Agricultural Economics* 23: 231–40.

Unnevehr, L. and Grace, D. 2013. *Aflatoxin Solutions for Improved Food Safety*. International Food Policy Research Institute (IFPRI) 2020 Focus Brief 20. IFPRI, Washington, DC, USA.

Upadhyaya, H.D. and Dwivedi, S.L. 2015. 'Global perspectives on groundnut production, trade, and utilization: Constraints and opportunities'. In: *National Seminar on Technologies for Enhancing Oilseeds Production Through NMOOP*, 18–19 January 2015. Professor Jayashankar Telangana State Agricultural University, Hyderabad, India.

Upadhyaya, H.D., Reddy, L.J., Gowda, C.L.L. and Singh, S. 2006. 'Identification of diverse groundnut germplasm: Sources of early maturity in a core collection. *Field Crops Research* 97 (2–3): 261–271.

Uriah, N. and Ogbadu, L. 1982. 'Influence of wood smoke on aflatoxin production by *Aspergillus flavus*'. *European Journal of Applied Microbiology and Biotechnology* 14: 51–53.

Van der Bijl, P., Stockenstrom, S., Vimer, H.F. and Van Wyk, C.W. 1996. 'Incidence of fungi and aflatoxins in imported areca nut samples'. *South African Journal of Science* 92: 154–156.

Van der Merwe, P.J.A. 2012. *Determinants of the Supply-side Fragmentation of Maize Storage in the North Western Free State Production Area*. BA(Hons) 10646116. Mini-dissertation submitted in partial fulfilment of a Masters in Business Administration. Potchefstroom Campus, North-West University, Potchefstroom, South Africa.

Van der Merwe, P.J.A., Subrahmanyam, P., Hildebrand, G.L., Reddy, L.J., Nigam, S.N., Chiyembekeza, A.J., Busolo-Bulafu, C.M. and Kapewa, T. 2001. 'Registration of groundnut cultivar ICGV-SM 90704 with resistance to groundnut rosette'. *International Arachis Newsletter* 21: 19–20.

Varga, J., Frisvad, J.C. and Samson, R.A. 2009. 'A reappraisal of fungi producing aflatoxins'. *World Mycotoxin Journal* 2: 263–277.

Varga, J., Frisvad, J.C. and Samson, R.A. 2011. 'Two new aflatoxin producing species, and an overview of *Aspergillus* section *Flavi*'. *Studies in Mycology* 69**:** 57–80.

Viljoen, J.H., Marasas, W.F.O. and Thiel, P.G. 1993. 'Fungal infection and contamination of commercial maize'. *In* Taylor, J.R.N., Randall, P.G. and Viljoen, J.H. (eds.), *Cereal Science and Technology: Impact on Changing Africa*. CSIR, Pretoria, South Africa.

Villers, P. 2014. 'Aflatoxins and safe storage'. *Frontiers in Microbiology* 5: 158.

Villers, P. 2015. 'Aflatoxin growth versus safe pre-and post-harvest drying and storage'. *Journal of Post-Harvest Technology* 3(3): 58–66.

Vinitketkumnuen, U., Chewonarin, T., Kongtawelert, P., Lertjanyarak, A., Peerakhom, S. and Wild, C.P. 1997. 'Aflatoxin exposure is higher in vegetarians than nonvegetarians in Thailand'. *Natural Toxins* 5: 168–71.

Vrabcheva, T.M. 2000. 'Mycotoxins in spices'. *Vopr Pitan* 69: 40–43 (in Russian).

Wacoo, A.P., Wendiro, D., Vuzi, P.C. and Hawumba, J.F. 2014. 'Methods for detection of aflatoxins in agricultural food crops'. *Journal of Applied Chemistry* Article ID 706291,15 pages.

Wagacha, J.M. and Muthomi, J.W. 2008. 'Mycotoxin problem in Africa: current status, implications to food safety and health and possible management strategies'. *International Journal of Food Microbiology* 124 (1): 1–12.

Walaa, S.E., Neama, A.M., Weam, S.E., Emad, M.M.K. and Khaled, M. 2015. 'Synthesis, and evaluation of cytotoxic activities of novel quinazolin derivatives'. *International Journal of Research in Pharmaceutical Science* 6 (1): 62–74.

Waliyar, F., Ba, A., Hassan, H., Bonkoungou, S. and Bosc, J.P. 1994. 'Sources of resistance to *Aspergillus flavus* and aflatoxin contamination in groundnut genotypes in West Africa'. *Plant Disease Journal* 78: 704–708.

Waliyar, F. and Hassan, H. 1993. 'Aflatoxin contamination of groundnut in Niger'. *In* Waliyar, F., Ntare, B.R. and Williams, J.H. (eds.) *Summary Proceedings of the Third ICRISAT Regional Groundnut Meeting for West Africa* (14–17 September 1992, Ouagadougou, Burkina Faso). International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India.

Waliyar, F., Kumar, K.V.K., Diallo, M., Traore, A., Mangala, U.N., Upadhyaya, H.D. and Sudini, H. 2016. 'Resistance to pre-harvest aflatoxin contamination in ICRISAT's groundnut mini core collection'. *European Journal of Plant Pathology* 1–13.

Waliyar, F., Kumar, P.L., Traore, A., Ntare, B.R., Diarra, B. and Kodio, O. 2008a. 'Pre- and Post-Harvest Management of Aflatoxin Contamination in Peanuts'. *In* Leslie, J., Bandyopadhyay, R. and Visconti, A. (eds.), *Mycotoxins Detection Methods, Management, Public Health and Agricultural Trade*. CABI, Oxford, UK.

Waliyar, F., Osiru, M., Sudini, H.K and Njoroge, S. 2013. 'Reducing aflatoxins in groundnuts through integrated management and biocontrol'. *In* Unnevehr, L. and Grace, D. (eds.) *Aflatoxins: Finding Solutions for Improved Food Safety*. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/publication/aflatoxins-finding-solutions-improved-food-safety

Waliyar, F., Siambi, M., Jones, R., Reddy, V., Chibonga, D., Kumar, P.L. and Denloye, S. 2008b. 'Institutionalizing mycotoxin testing in Africa. *In* Leslie, J.F., Bandyopadhyay, R. and Visconti, A. 2008. *Mycotoxin Detection Methods, Management, Public Health and Agricultural Trade*. CABI Books, Wallingford, UK.

Waliyar, F., Umeh, V.C., Traore, A., Osiru, M., Ntare, B.R., Diarra, B., Kodio, O., Kumar, K.V. and Sudini, H. 2015. 'Prevalence and distribution of aflatoxin contamination in groundnut (*Arachis hypogaea* L.) in Mali, West Africa'. *Crop Protection* 70: 1–7.

Wang, J.S., Huang, T., Su, J., Liang, F., Wei, Z., Liang, Y. and Groopman, J.D. 2001. 'Hepatocellular carcinoma and aflatoxin exposure in Zhuqing village, Fusui County, People's Republic of China'. *Cancer Epidemiology Biomarkers & Prevention* 10 (2): 143–146.

Wang, W., Lawrence, K.C., Ni, X., Yoon, S.C., Heitschmidt, G.W. and Feldner, P. 2015. 'Near-infrared hyperspectral imaging for detecting Aflatoxin B 1 of maize kernels'. *Food Control* 51: 347–355.

Wang, Z., Liu, J., Lee, D., Scully, B. and Guo, B. 2008. 'Postharvest *Aspergillus flavus* colonization in responding to preharvest field condition of drought stress and oligo-macroarray profiling of developing corn kernel gene expression under drought stress'. *Phytopathology* 98: S166.

Wanjiru, E. 2011. 'Kenya: Investors target harvest with mobile maize dryers'. *Bussiness Daily* [online] 2 August 2011. Available at: http://allafrica.com/stories/201108020988.html [Accessed 27 September 2016].

Ware, G. 1991. *Inspection, Sampling and Analysis of Maize and Groundnuts for Aflatoxin*. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Warth, B., Parich, A., Atehnkeng, J., Bandyopadhyay, R., Schuhmacher, R., Sulyok, M. and Krska, R. 2012. 'Quantitation of mycotoxins in food and feed from Burkina Faso and Mozambique using a modern LC-MS/MS multitoxin method'. *Journal of Agricultural and Food Chemistry* 60 (36): 9352–9363.

Wartu, J.R., Whong, C.M.Z., Umoh, V.J. and Diya, A.W. 2015. 'Occurrence of aflatoxin levels in harvest and stored groundnut kernels in Kaduna State, Nigeria'. *Journal of Environmental Science, Toxicology and Food Technology* 9 (1): 62–66.

Watson, S., Diedhiou, P.M., Atehnkeng, J., Dem, A., Bandyopadhyay, R., Srey, C., Routledge, M.N. and Gong, Y.Y. 2015. 'Seasonal and geographical differences in aflatoxin exposures in Senegal'. *World Mycotoxin Journal* 8(4): 525–531.

Wei, W., Lawrence, K.C., Yoon, X.N., Heitschmidt, S.C. and Feldner, G.W. 2015. 'Near-infrared hyperspectral imaging for detecting Aflatoxin B_1 of maize kernels'. *Food Control* 51: 347–355.

Whitaker, T. 2003. 'Detecting mycotoxins in agricultural commodities'. *Molecular Biotechnology* 23: 61–71.

Whitaker, T., Slate, A., Doko, B., Maestroni, B. and Cannavan, A. (eds.). 2011. *Sampling Procedures to Detect Mycotoxins in Agricultural Commodities*. Springer Link, London, UK

Wicklow, D.T., Vesonder, R.F., Mcalpin, C.E., Cole, R.J. and Roquebert, MF. 1989. 'Examination of *Stilbothamnium togoense* for *Aspergillus flavus* group mycotoxins'. *Mycotoxin* 34: 249–252.

Wild, C.P., Fortuin, M., Donato, F., Whittle, H.C., Hall, A.J. and Wolf, C.R. 1993. 'Aflatoxin, liver enzymes, and hepatitis B virus infection in Gambian children'. *Cancer Epidemiology Biomarkers and Prevention* 2: 555–561.

Wild, C.P. and Hall, A.J. 2000. 'Primary prevention of hepatocellular carcinoma in developing countries'. *Mutation Research* 462: 381–393.

Wild, C.P., Hudson, G.J., Sabbioni, G., Chapot, B., Hall, A.J. and Wogan, G.N. 1992. 'Dietary intake of aflatoxins and the level of albumin-bound aflatoxin in peripheral blood in The Gambia, West Africa'. *Cancer Epidemiology Biomarkers and Prevention* 1: 229–234.

Wild, C.P., Jiang, Y.Z., Sabbioni, G., Chapot, B. and Montesano, R. 1990. 'Evaluation of methods for quantitation of aflatoxin-albumin adducts and their application to human exposure assessment'. *Cancer Research* 50 (2): 245–51.

Wild, C.P., Pionneau, F.A., Montesano, R., Mutiro, C.F. and Chetsanga, C.J. 1987. 'Aflatoxin detected in human breast milk by immunoassay'. *International Journal of Cancer* 40 (3): 328–333.

Wild, C.P., Rasheed, F.N., Jawla, M.F., Hall, A.J., Jansen, L.A. and Montesano, R. 1991. 'In-utero exposure to aflatoxin in West Africa'. *Lancet* 337: 1602.

Wild, C.P., Yin, F., Turner, P.C., Chemin, I., Chapot, B. and Mendy, M. 2000. 'Environmental and genetic determinants of aflatoxin albumin adducts in the Gambia'. *International Journal of Cancer* 86: 1–7.

Will, M.E., Holbrook, C.C. and Wilson, D.M. 1994. 'Evaluation of field inoculation for reaction to preharvest *Aspergillus flavus* group infection and aflatoxin contamination'. *Peanut Science* 21: 122–123.

Williams, J.H., Phillips, T.D., Jolly, P.E., Stiles, J.K., Jolly, C.M. and Aggarwal, D. 2004. 'Human aflatoxicosis in developing countries: A review of toxicology, exposure, potential health consequences, and interventions'. *The American Journal of Clinical Nutrition* 80 **(**5): 1106–1122.

Williams, W.P., Krakowsky, M.D., Scully, B.T., Brown, R.L., Menkir, A., Warburton, M.L. and Windham, G.L. 2015. 'Identifying and developing maize germplasm with resistance to accumulation of aflatoxins'. *World Mycotoxin Journal* 8**:** 193–209.

Wilson, D.M. and Payne, G.A. 1994. 'Factors affecting *Aspergillus flavus* group infection and aflatoxin contamination of crops'. *In* Eaton, D.L. and Groopman, J.D. (eds.), *The Toxicology of Aflatoxins. Human Health, Veterinary, and Agricultural Significance*. Academic Press, San Diego, California.

World Medical Association (WMA). 2004. *World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects.*World Medical Association, Ferney-Voltaire, France.

World Health Organization (WHO). 2005. *Impacts of Aflatoxins on Health and Nutrition. Report of an Expert Group Meeting*. WHO, Brazzaville, Congo.

World Health Organization (WHO). 2006. 'Mycotoxins in African foods: Implications to food safety and health'. *AFRO Food Safety Newsletter* 2: 1–5.

World Bank. 2007. *Sudan - Dimensions of Challenge for Development in Darfur. A Background Volume*. World Bank, Washington, DC, USA.

Wotton, H.R. and Strange, R.N. 1985. 'Circumstantial evidence for phytoalexin involvement in the resistance of peanuts to *Aspergillus flavus*'. *Journal of General Microbiology* 131: 487–494.

Wotton, H.R. and Strange, R.N. 1987. 'Increased susceptibility and reduced phytoalexin accumulation in drought-stressed peanut kernels challenged with *Aspergillus flavus*'. *Applied and Environmental Microbiology* 53: 270–273.

Wu, F. 2007. 'Bt corn and mycotoxin reduction'. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 2: 1–8.

Wu, F. and Khlangwiset, P. 2010. 'Health and economic impacts and cost-effectiveness of aflatoxin-reduction strategies in Africa: Case studies in biocontrol and postharvest interventions'. *Food Additives & Contaminants* 27: 496–509.

Wyers, M., Mobio, M.G., Schricke, E. and Nguetta, A. 1991. 'Search for lesions due to aflatoxin-B_1 contamination of feed in three industrial hen farms in Cote d'Ivoire'. *Revue d'Elevage et de Medecine Veterinaire des Pays Tropicaux* 44 (1): 15–21.

Yard, E.E., Daniel, J.H., Lewis, L.S., Rybak, M.E., Paliakov, E.M., Kim, A.A. and Sharif, S.K. 2013. Human aflatoxin exposure in Kenya, 2007: A cross-sectional study'. *Food Additives & Contaminants: Part A* 30 (7): 1322–1331.

Younis, Y.M. and Malik, K.M. 2003. 'TLC and HPLC assay of aflatoxin contamination in Sudanese peanuts and peanut products'. *Kuwait Journal of Science and Engineering* 30 (1): 79–93.

Yousif, I.M., Mariod, A.A., Elnour, I.A. and Mohamed, A.A. 2010. 'Determination of aflatoxin levels in Sudanese edible oils'. *Food and Chemical Toxicology* 48 (8): 2539–2541.

Youssef, M.S. 2009. 'Natural occurrence of mycotoxins and mycotoxigenic fungi on Libyan corn with special reference to mycotoxin control'. *Research Journal of Toxins* 1 (1): 8–22.

Youssef, M.S., Abo-Dahab, N.F. and Abou-Seidah, A.A. 2000. 'Mycobiota and mycotoxin contamination of dried raisins in Egypt'. *African Journal of Mycology and Biotechnology* 8 (3): 69–86.

Yu, J., Fedorova, N.D., Montalbano, B.G., Bhatnagar, D., Cleveland, T.E., Bennett, J.W. and Nierman, W.C. 2011. 'Tight control of mycotoxin biosynthesis gene expression in *Aspergillus* flavus by temperature as revealed by RNA-Seq'. FEMS Microbiology Letters 322(2): 145–9.

Zalar, P., Frisvad, J.C., Gunde, Đ., Cimerman, N., Varga, J. and Samson, R.A. 2008. 'Four new species of *Emericella* from the Mediterranean region of Europe'. *Mycologia* 100: 779–795.

Zewde, G. 2011. *Safety of Animal Source foods in Ethiopia – A Situational Analysis*. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Zinedine, A., Brera, C., Elakhdari, S., Catano, C., Debegnach, F., Angelini, S. and Miraglia, M. 2006. 'Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco'. *Food Control* 17 (11): 868–874.

Zinedine, A., Gonzalez-Osnaya, L., Soriano, J.M., Moltó, J.C., Idrissi, L. and Manes, J. 2007a. 'Presence of aflatoxin M_1 in pasteurized milk from Morocco'. *International Journal of Food Microbiology* 114(1): 25–29.

Zinedine, A., Juan, C., Soriano, J.M., Moltó, J.C., Idrissi, L. and Mañes, J. 2007b. 'Limited survey for the occurrence of aflatoxins in cereals and poultry feeds from Rabat, Morocco'. *International Journal of Food Microbiology* 115: 124–127.

Zuber, M.S., Darrah, L.L., Lillehoj, E.B., Josephson, L.M., Mfanwiller, N.W., Thompson, D.L., Bockholt, A.J. and Brewbaker, J.L. 1983. 'Comparison of open pollinated maize varieties and hybrids for preharvest aflatoxin contamination in southern United States'. *Plant Disease* 67: 185–187.

The Technical Centre for Agricultural and Rural Cooperation (CTA) is a joint international institution of the African, Caribbean and Pacific (ACP) Group of States and the European Union (EU). Its mission is to advance food security, resilience and inclusive economic growth in Africa, the Caribbean and the Pacific through innovations in sustainable agriculture.

CTA operates under the framework of the Cotonou Agreement and is funded by the EU.

For more information on CTA, visit **www.cta.int**

Contact us
CTA
PO Box 380
6700 AJ Wageningen
The Netherlands

Tel: +31 317 467100
Fax: +31 317 460067
Email: cta@cta.int

www.facebook.com/CTApage
@CTAflash