Food Safety Challenges: The Case of Aflatoxin

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Introduction

Aflatoxins are naturally occurring toxins (CODEX, 2013) that are poisonous to human beings and animals (Van Egmond *et al*., 2007). Poisoning occurs mainly through consumption of contaminated crop and animal products, but also through inhalation and absorption through the skin (Wagacha and Muthomi, 2008). The toxins are produced by some species of *Aspergillus* fungi (mould), which are widely distributed (Hedayati *et al*., 2004), and mainly found in cereals, oil seeds, spices and tree nuts. Under favourable high-temperature and -moisture conditions common in the tropics and sub-tropics (Thompson and Henke, 2000), the fungi produce at least 16 related toxins. There are four major ones (B1, B2, G1 and G2) with B1 being the most common and the most toxic (Hedayati *et al*., 2004). If animals eat feed contaminated with aflatoxin B1, it is broken down into a more potent toxin (M1), which contaminates animal products such as eggs, meat and milk (Kangethe and Langat, 2009, Demirhan and Yentür, 2014). Aflatoxins are resistant to heat and have been detected in pasteurized milk, cheese, peanut butter, cereal-based African traditional alcoholic beverages and infant foods (Dwivedi *et al*., 2004, Muthomi *et al.*, 2012, Kengethe and Langat, 2009, Offifah and Adesiyun, 2007).

Aflatoxins are major challenges to the global food safety systems, health and nutrition and economies because they are produced during crop production, harvesting, transportation, storage and food processing (Murphy *et al*., 2006),. Exposure to high levels of aflatoxin leads to death from liver failure (Chao *et al*., 1991) and the most devastating case occurred in Kenya in 2004 (Lewis *et al*., 2005). Extended exposure to low levels (chronic poisoning) is suspected to cause liver cancer (MRC, 2001), reduced growth and kwashiorkor (protein malnutrition) in children (Okoth and Ohingo, 2004) and reduced ability to fight invasion by other disease-causing agents. Economic losses, particularly the financial burden on health care, disposal of contaminated food and feed, reduced productivity and barrier to trade, are enormous. The US Centers for Disease Control (CDC) have estimated that more than 4.5 billion people in developing countries are chronically exposed to toxins produced by various fungi, but primarily aflatoxins in their diets (CDC, 2004). These toxins are considered by US Food and Drug Administration and other regulatory agencies to be unavoidable contaminants of foods, hence the goal is to minimize contamination in foods and feeds through the application of standards and by enforcement of legislation. The maximum aflatoxin residue allowed in human foods is 4-30 μg/kg, depending on the country involved (FDA, 2004), except for milking. To minimize contamination, use of good agricultural and manufacturing practices is recommended, but the risk still exists if due care/attention is not paid.

Box 1: The largest case of aflatoxin poisoning documented worldwide occurred in Kenya in 2004 and resulted in 317 case-patients and 125 deaths, as reported in the local medical facilities. This was associated with consumption of home-grown maize stored under damp conditions (CDC, 2004, Lewis et al., 2005).

Box 2: Pre-harvest practices to minimize aflatoxin contamination entails use of good agricultural practices including: proper disposal of previous crop remains, crop rotation, growing tolerant crop variety (if available), timely planting, right plant density, good soil fertility, avoid moisture stress, timely pest and weed control and harvesting.

Risk of aflatoxin contamination in the field & disease-resistant varieties

Aspergillus mould produces a tough resting structure (sclerotia), which allows it to survive in the soil, discarded products and in plant remains. In the absence of crop rotation, the fungus is able to infect maturing crops (Jaime-Garcia and Cotty, 2004, Olanya *et al*., 1997). Plants are most prone to *Aspergillus* attack when grown under sub-optimal conditions such as moisture stress, low soil fertility and infestation with pests and weeds (Holbrook *et al*., 2004, Wagacha and Muthomi, 2008). Timely harvesting and threshing reduces aflatoxin contamination (Rachaputi *et al*., 2002) but some farmers delay harvesting because of labour constraints. Further, if farmers plant varieties prone to *Aspergillus* attack and off-season rains fall during harvesting, the likelihood of contamination is high. It is critical that field contamination of crops is minimized because fungal growth and aflatoxin production continue with increasing vigour at postharvest and storage stages (Alakonya *et al*., 2009).

One of the most promising long-term strategies in aflatoxin control is the development of resistant varieties. Sources of resistance to aflatoxin have been identified and introduced into public and private breeding programs (Wagacha and Muthomi, 2008). Also, two maize lines that are resistant to aflatoxin have been identified but few if any, commercial cultivars have adequate levels of resistance to aflatoxin producing fungi. In the USA, biological control measures that involve adding strains of nontoxigenic *Aspergillus* to the soil to outcompete the toxigenic *Aspergillus* strains are being used to reduce contamination on peanuts and maize (Dorner and Cole, 2002). However, these biological control products cannot be used in other countries because, to be effective, the nontoxigenic strain must originate from the soils where it will be used (Yin *et al*., 2008). In Africa, trials on biological control of aflatoxin using local strains are ongoing in Kenya and Nigeria, but at a more advanced stage in the latter where maize farmers have realized about 80% reduction in aflatoxin contamination (IITA, 2010). Further, commercialization of the product will require private-public partnership for mass production, marketing and distribution.

Product contamination during postharvest handling

The postharvest handling techniques used can contribute to contamination as crops are still at risk after harvest. For example, if they come into direct contact with soil beaten with sticks, cracks occur through which aflatoxin producing fungus enter. Additionally, most smallholder farmers rely on sun drying, exposing the product to weather fluctuations. Consequently, prolonged drying and failure to reach the desired moisture content (e.g. below 10% for peanuts and below 15.5% for maize) provides favourable conditions for fungal growth and aflatoxin build-up (Bhat and Visanthi, 2003). At the farm gate, physical removal of discoloured and mouldy grains can reduce contamination, but because the contaminated product may appear normal and without signs of fungal infection, the only accurate means to confirm aflatoxin contamination is to conduct a quality control test to determine the absence or presence of the toxin (Muthomi *et al*., 2012). However, low-cost rapid field-based test kits are not readily available to most small-scale producers. Also, most smallholder farmers lack accurate information on factors favouring aflatoxin build-up and its effect on human and animal health (Kangethe and Langat, 2009). As a result, contaminated grains are sometimes processed into alternative foods for human consumption or used to feed animals (Alakonya *et al*., 2009, Nikander *et al*., 1991). Furthermore, even well-dried products can be contaminated with spores floating in the atmosphere and pick up moisture if appropriate packaging materials and mode of transportation are not used. Thus, farmers, traders and processors need access to training and adequate processing and quality control equipment so that they can put the necessary

Box 3: Postharvest handling practices to minimize aflatoxin contamination of product include: Avoid direct contact of product with the soil, use appropriate technology and minimize damage, fast drying to right moisture content, use appropriate packaging materials and mode of transport, pest control, store product in airtight bags in well-aerated stores, clean stores before loading new products

measures in place to minimize fungal growth and aflatoxin build-up when handling food and feed (Bhat and Vasanthi, 2003).

Risk of contamination during storage

Even in storage, aflatoxin build up can be a challenge. The fungi do not thrive under low-oxygen conditions (Wagacha and Muthomi, 2008), and contamination can be minimized by use of air-tight, moisture proof bags. These are in limited use in some African countries and they cost more than conventional bags. Pest infestation, especially insects, also cause an increase in moisture content and temperature, thereby creating favourable conditions for fungal growth (St. Leger *et al*., 2000). Thus, pest control is important. Further, some producers lack appropriate stores and bags containing produce can come into direct contact with the floor where temperature and condensation are relatively high. These conditions favour aflatoxin build-up. All grain and related products including animal feed should be stored under dry conditions. An effective strategy for aflatoxin control in peanuts exists, and is already in use in Haiti and is being promoted by CTA (Box 4). The control measure can be used in other countries, regions and also for other crops and countries.

Box 4: Aflatoxin control in groundnuts at (a) production stage involves: crop rotation, use of high quality seeds of early maturing, drought tolerant and disease resistant varieties, timely planting on fertile soils, proper control of pests and diseases (b) harvest/Post harvest stage: timely harvesting, avoid mechanical damage to pods, fast drying and threshing immediately using tarpaulins, ground nuts dried below 10% moisture, sorting to remove damaged, immature or rotten nuts, packaging in clean breathable bags and storing groundnuts in unshelled form for as long as possible in cool well aerated stores with pest control (dried neem leaves is effective for insect control), during marketing conduct moisture tests, use simple lateral flow dipstick tests for aflatoxin, ensure traceabilty of the product, created awareness about aflatoxin along the entire value chain and encourages two way flow of information (CTA Top innovation: Aflatoxin control)

Conclusions

1. Aflatoxin-producing fungus can contaminate the product at all stages of the value chain from the field, during harvesting, transportation, storage and food and feed processing.

2. To address the challenge of aflatoxin contamination requires well-empowered farmers with knowledge and skills on how to produce products with reduced levels of aflatoxin, availability of cost-effective processing technology and quality control measures, well-informed traders and processors on how to minimize contamination during transportation and storage, strengthened surveillance for aflatoxin contamination and robust aflatoxin testing facilities.

3. The use of good agricultural and manufacturing practices requires supportive institutional and policy environment. Thus, there is need to (a) have strong regulatory frameworks and enforce adherence to set standards, (b) support research to have the evidence on key trigger points along the commodity value chains to support interventions, develop fast, simple and affordable aflatoxin

testing capability as well as improved and resistant varieties and alternative uses and safe methods of disposal of of contaminated produce, and(c) build the capacity of farmers and improve their access to adequate processing, aflatoxin testing and storage facilities.

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