Feed the Future Innovation Lab for Food Security Policy

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The co-occurrence of aflatoxin and fumonisin along the maize value chain in southwest Nigeria

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Introduction

Aflatoxins and fumonisins are two major groups of mycotoxins produced by the *Aspergillus* and *Fusarium* genera of fungi respectively. These naturally occurring toxins frequently contaminate maize, mainly in countries with high temperature and humidity (Paterson and Lima 2017). Several studies have demonstrated these mycotoxins as potential risk to human and animal health (Wu et al. 2014).

Aflatoxin B1 (AFB1) is classified as a group 1 human carcinogen (IARC, 2002). It is known to be the second leading cause of hepatocellular carcinoma (HCC) worldwide and the risk of HCC is multiplicatively higher (30 times) for individuals who have chronic hepatitis B virus (HBV) infection (JECFA 1998, Wu et al. 2013). High doses of aflatoxin can result in acute aflatoxicosis, severe liver damage, edema and even death. Aflatoxins are associated with inducing adverse immune system and growth effects in animals (Bondy and Pestka, 2000) and growth impairment in children (Khlangwiset et al. 2011). Recent studies have also found that aflatoxin exposure may be associated with risks of prematurity and pregnancy loss (Smith et al. 2017).

Fumonisin B1 (FB_1) is classified as a group 2B carcinogen (IARC, 2002). It's contamination in maize has been associated with the incidence of esophageal and liver cancers (Sun et al., 2007, 2011). Dietary exposure of fumonisin in pregnant mothers has also been associated with the incidence of neural tube defects in infants (Missmer et al., 2006). Recent studies have associated fumonisin exposure with growth impairment in children (Shirima et al. 2015, Chen et al. 2018a, 2018b).

Several animal and *in vitro* studies of aflatoxin-fumonisin co-exposure indicate additive or synergistic effects on the development of precancerous lesions or liver cancer in laboratory animals and in vitro studies (WHO, 2018). A study in broilers (chicks) indicated that co-exposure to AFB_1 and FB_1 had primarily additive effects on body weight, liver structure and immunological response (Tessari et al., 2006).

Key Findings

- People in Nigeria are at risk of exposure to mycotoxins (aflatoxins and fumonisins) which both have potential risk to human and animal health
- We find evidence that many maize products (51.7% of our samples) had total aflatoxin levels above the regulatory limits in Nigeria while 12.93% of the samples contained total fumonisin levels higher than the United States regulatory limit
- Aflatoxin and fumonisin contamination in maize products extend beyond production to storage and final food products
- Adequately addressing the mycotoxin challenge requires consideration of the entire maize value chain

Despite these potentially dangerous effects of the co-occurrence of aflatoxins and fumonisins on humans and animals, only a limited number of studies have explored the co-occurrence of these mycotoxins in foods consumed as key staples, and no such studies exist along supply chains in sub-Saharan Africa. This study attempts to begin to fill this gap by exploring the occurrence and co-occurrence of aflatoxins and fumonisins in the supply chain of maize, a key staple in sub-Saharan Africa. In this study, the occurrence and co-occurrence of aflatoxins (AFB1, AFB2, AFG1 and AFG2) and fumonisins (FB1, FB2 and FB3) along the maize value chain in southwest Nigeria is reported. Rather than just focusing on maize samples from one node of the value chain (e.g. maize from farmers or maize based products in retail outlets), we explore this phenomenon in samples collected from actors all along the maize supply chain. This includes farmers, maize traders (after different lengths of storage), feed millers (maize and final feed) and retailers of maize based products.

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This is important because the maize value chain in Nigeria (as in many parts of SSA) is often a long and fragmented supply chain with many actors (Liverpool-Tasie et al. 2018). This creates many opportunities for aflatoxin and fumonisin contamination during maize production as well as during handling and storage. Looking at maize based products along the maize value chain provides key insights as to where along such value chains (and in what form of maize based products) the challenge of mycotoxin contamination occurs generally and where the co-occurrence of aflatoxins and fumonisins presents particular health concerns.

Data

The study area is the Greater Ibadan Area of Oyo State in Southwest Nigeria. This area was selected for several reasons. First, in addition to maize consumption by humans, southwest Nigeria (and Oyo State particularly) is a major zone for poultry production and aquaculture. Thus, this zone of the country is a major driver of increased maize demand (for animal feed). Second, the study area was selected because of its higher probability of exposure to mycotoxin challenges. Farmers from two local government areas (LGAs[1]) of Oyo State, Atisbo and Saki West were selected for the samples of maize. Three major maize wholesale markets in the Greater Ibadan area of Oyo State, Nigeria were selected for collection of maize samples from traders. One wholesale market is located in an urban area (Bodija market), one in a rural-near-city area (Ojaoba market) and the other in an off-market area[2]. Ten feed-mills from two LGAs (Lagelu and Egbeda) of the greater Ibadan area of Oyo state (identified by stakeholders in the poultry subsector as the areas with high concentrations of feed mills) were selected for the collection of poultry feed and maize samples. Upstream the maize value chain, samples of final consumer products made from maize based products were purchased from the two main wholesales markets (Bodija and Ojaoba) in the study area. The identified products were broadly categorized into branded and unbranded maize based products.

Main findings

In farmer's stored maize, the total aflatoxin level in the samples tends to increase with time of storage but the total fumonisin levels do not follow any specific pattern with length of storage time

Aflatoxin and fumonisin levels in maize samples were collected from farmers, from harvest to 4 months of storage at 1-month intervals. The geometric mean of total aflatoxin level at harvest was 4.2 ppb but after 4 months of storage, the level went up to 42.7 ppb which is much higher than the Nigerian maximum total aflatoxin regulatory limit in maize of 4 ppb. At harvest, 37.5% of the samples had aflatoxin levels more than 4 ppb and after 4 months of storage 87.5% of the samples had aflatoxin levels > 4 ppb (Figure 1). On the other hand, the results for the total fumunosin levels are inconclusive. The highest geometric mean level of total fumonisin was observed in samples collected at harvest (1682.3 ppb); 37.5% of the samples collected at harvest had total fumonisin levels higher than the United States Food and Drug Administration (USFDA) regulatory limit of 2000 ppb (USFDA, 2000) (Figure 2).

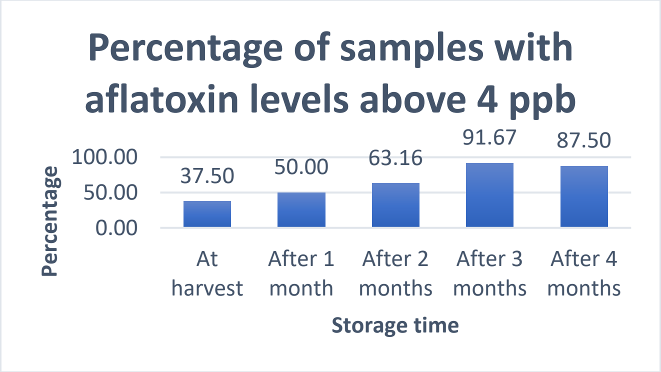

Figure 1: Bar graph showing the percentage of farmer's samples containing total aflatoxin levels above the allowable limit in Nigeria

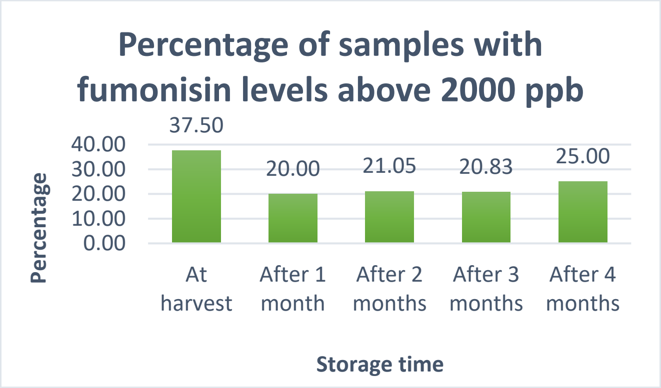

Figure 2: Bar graph showing the proportion of farmer's samples containing total fumonisin levels above maximum acceptable level set by the USFDA

[1] LGAs are the third level of government administration in Nigeria, similar to counties in the USA.

[2] An "off market area" means it is adjacent to but outside the actual market

In maize from local maize traders the total aflatoxin and total fumonisin levels do not follow any specific pattern with length of storage time

The total aflatoxin and fumonisin levels in maize samples collected from maize traders after 1 week and 2 weeks of storage. The geometric mean levels of total aflatoxin and total fumunosin in the maize trader's samples at different storage times were not statistically significantly different ($p > 0.05$)

In maize samples from feed millers the total aflatoxin levels in the final feed is much greater than in the stored maize but there is no difference for the total fumunosin levels

The total aflatoxin and fumonisin levels in maize flour samples were collected from feed millers from their storage and feed samples produced out of their stored maize. All of the total feed samples collected from the feed millers had aflatoxin levels higher than 20 ppb which is the maximum allowable limit in feed set by the USFDA (USFDA, 2000). 10% of the stored maize samples and also the final feed samples contained fumonisins levels higher than the USFDA regulatory limits of 2000 ppb in feed.

For branded and non-branded maize-based food products, total aflatoxins levels in samples from farmers, maize traders, feed millers and maize retailers are well above the national regulatory limits

The geometric means of total aflatoxin levels in farmer's maize samples stored for 2-4 months, samples from maize traders stored for over 2 weeks, final feed samples from feed millers and the non-branded maize snacks were higher than 4 ppb which exceeded the set maximum limit for total aflatoxin level in maize by the Standards Organization of Nigeria (Figure 3). The geometric means of total aflatoxin levels in other groups were comparatively lower and can be considered safe or acceptable. However, the geometric means of total fumonisin levels in all the group of samples collected were much less than the USFDA regulatory limit of 2000 ppb (Figure 4).

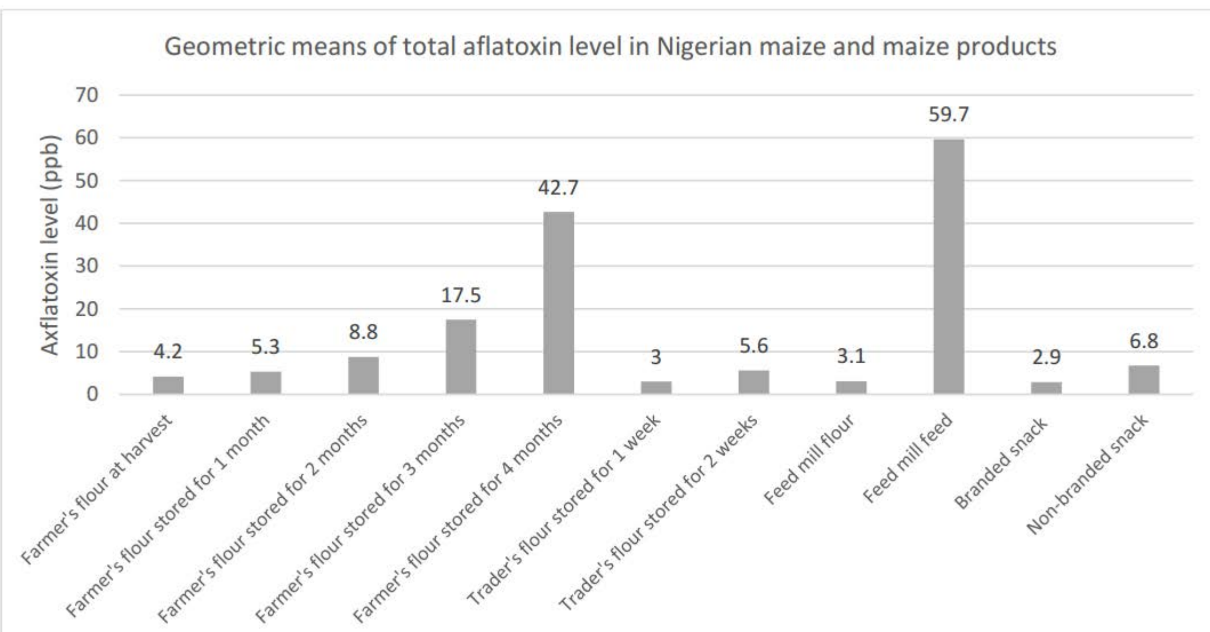

Figure 3: Bar graph showing the geometric means of total aflatoxin levels in Nigerian maize and maize products

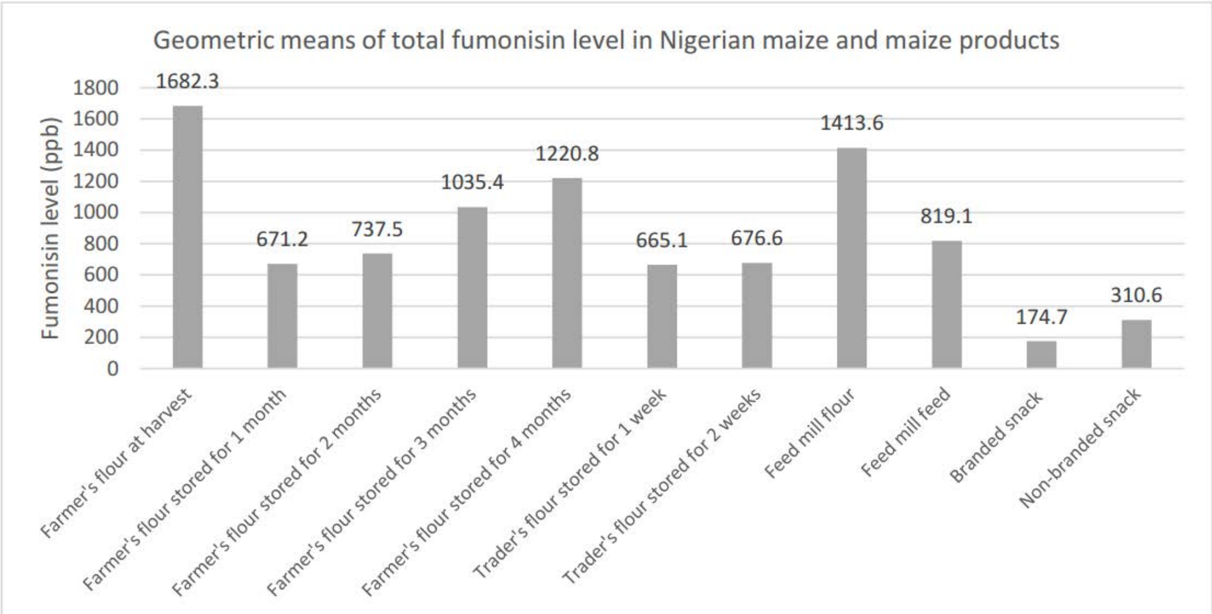

Figure 4: Bar graph showing the geometric means of total fumonisin levels in Nigerian maize and maize products

Policy implications

Research and policy interventions that support the development and dissemination of improved maize varieties that are resistant to fungal infection and mycotoxin control on maize fields are important (Dorner and Horn 2007, Khlangwiset and Wu 2010). They occur alongside efforts to reduce exposure during production such as early harvesting followed by rapid drying (Stinson, 1980). These efforts may need to be accompanied by measures to prevent the exposure of grain to the fungi along the entire value chain, from harvest to during storage and for food products in stores and homes. Due to the prevalence of multiple ingredients in most food and feed, minimizing human and animal exposure to dangerous mycotoxins requires consideration of multiple related supply chains such as maize and groundnut products in the case of animal feed. Efforts to understand and address challenges associated with mycotoxins in maize based products need to be more holistic and to consider the potential for exposure of the grain to these harmful fungi along the entire supply chain and across related supply chains.

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