Building an Aflatoxin Safe East African Community

Technical Policy Paper 4

Aflatoxin: Impact on Animal Health and Productivity

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Situational Analysis East Africa Region

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Authors:

Delia Grace, International Livestock Research Institute, Nairobi, Kenya

Erastus Kang'ethe, University of Nairobi, Kenya

Johanna Lindahl, International Livestock Research Institute, Nairobi, Kenya

Christine Atherstone, International Livestock Research Institute, Kampala, Uganda

Francesca Nelson, International Institute of Tropical Agriculture, Dar es Salaam, Tanzania

Timothy Wesonga, East African Community, Arusha, Tanzania

Contact IITA:

f.nelson@cgiar.org or c.njuguna@cgiar.org

IITA Tanzania East Africa Region Hub
Plot No. 25, Mikocheni Light Industrial Area
Mwenge, Coca Cola Road, Mikocheni B
PO Box 54441, Dar es Salaam, Tanzania

Cover: An ILRI researcher with the son of a smallholder pig farmer in Uganda. *ILRI*.

Foreword

Livestock makes an important contribution to the economic livelihoods and nutritional wellbeing of people throughout East Afric. During 2104, livestock contributed to 9 percent of the gross domestic product (GDP) of Burundi, 9 percent in Kenya, 10 percent in Rwanda, and 8 percent in both Tanzania and Uganda. The ownership of livestock is intrinsic to the culture of the region and has expanded to peri-urban and urban areas over the past decade. The East African Community (EAC) estimates that the fisheries sector alone directly supports over 5 million people, generating 4 percent of the region's GDP through annual catches of approximately 878 tons of fish. Aquaculture has been highlighted as a promising area for growth to meet growing domestic demand as well as generate foreign exchange through export revenues. In tandem with fish and livestock, dairy products, especially milk, play an important role in furnishing essential minerals and protein in the diet that can be difficult or impossible to obtain through plant sources. The same nutrients contribute to the growth and development of infants and young children. Livestock products have the potential to reverse the burden of iron deficiency anemia in pregnant women and reduce maternal mortality.

The livestock and fisheries industries, while nascent, hold enormous potential. To realize this, improved feed quality and feed safety is a high priority. Traditionally for subsistence farmers and small holders, the poorest quality grains are cordoned off for animal feed. Similarly, formal markets differentiate, with the best quality sold to large millers for human consumption and secondary quality tagged for feed. Over time, the result of these practices has led to compromised health and reduced productivity of livestock and aquaculture operations in the region due to feeds contaminated with aflatoxin. Additionally, aflatoxin is transferred into animal tissue and dairy products. This is of particular concern due to the high consumption of milk by young children.

In this paper we present a comprehensive overview of the sector and discuss the available evidence of impacts of aflatoxin on animal health and productivity for the region. We hope that the establishment and sharing of this knowledge base will provide the foundation for policies and programs to address the food safety issues linked to aflatoxin-contaminated feeds. This is a necessary step in realizing the full economic potential of the livestock industry for the East Africa region.

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Executive Summary

Aflatoxins belong to a group of mycotoxins that are produced by fungi species (molds) as they grow on their substrates. The main fungi responsible for producing aflatoxins are *Aspergillus flavus* and *Aspergillus parasiticus* (Cary et al. 2005). Other species of fungi also produce aflatoxins (Pildain et al. 2008), but at lower concentrations. The fungi occur naturally in the soil in tropical regions and infect crops while on the farm (preharvest) and after harvest during storage (postharvest) and processing. The crops most infected include maize, groundnut, cassava, cotton, spices, dried and farmed fish, oilseeds, beans and nuts, and dried fruits.

Eighteen different types of aflatoxin are known. The major ones are aflatoxins B_1, B_2, G_1 and G_2, thus named depending on their fluorescence under blue and green light. Aflatoxin B_1 and B_2 fluoresce under blue light while G_1 and G_2 fluoresce under green light. Aflatoxin M_1 and M_2 are breakdown products of aflatoxin B_1, B_2, or G_1 and G_2 formed in the liver and excreted in the milk and urine (Henry et al. 2007) of mammals exposed to aflatoxin B_1, B_2, G_1, and G_2.

All animals are affected by aflatoxin. Rabbits, ducks, and pigs are highly susceptible; dogs, calves, turkey, and sheep are moderately susceptible; chickens and cattle are relatively resistant. Fish vary from highly susceptible to resistant, and honey bees are relatively resistant. Aflatoxins are probably not major causes of livestock disease and low productivity in Africa, but are contributing factors which are likely to become more important as livestock production intensifies. The animal feeds most likely to be contaminated are maize, cottonseed, copra, and groundnuts. In developing countries, animals may often be fed crops t considered unfit for human consumption because of mold, insect damage, or other problems. These feeds are at high risk for aflatoxin contamination. Aflatoxins cannot be detected by sight or smell in contaminated food or feed. Aflatoxins are not eliminated by boiling, cooking, or by processing into compound feeds.

Animal source foods, especially milk, may also contain aflatoxins if animals eat contaminated feeds. This is often the case with milk; carry-over rates are relatively high, consumption is high, and milk is often given to infants and young children who are most at-risk for negative health outcomes related to aflatoxin exposure. Carry-over rates of aflatoxins from feed to livestock products are much lower for meat and eggs. Given the relatively low quantities consumed, meat and eggs are not likely to present a major contribution to overall consumption of aflatoxins in the diet. Smoked fish and fermented foods, however, do present a risk, but this sector requires further assessment.

Aflatoxins have proven to have negative health impacts on animals, which include death from ingesting large amounts; lowered productivity; and immunosuppression. In mammals, aflatoxins mainly damage the liver. Key economic impacts of aflatoxins occur when feed or animal products fail to meet standards and cannot be exported or marketed.

There are few economic studies in the developing world on the impact of aflatoxin on the livestock sector. However, in aggregate, aflatoxin may cost African countries hundreds of millions of dollars annually. Moreover, across East Africa, regulatory enforcement of aflatoxin control is very expensive given the breadth of the problem across the East Africa region. Chronic aflatoxin consumption has greater economic- and health-related impacts than acute aflatoxicosis outbreaks. Impacts are likely to worsen as livestock industries intensify in response to growing demand for meat, milk, fish, and eggs.

Worldwide, aflatoxins are the most important contaminant of commercial animal feeds. In sub-Saharan Africa, most feed samples contain aflatoxin and many contain it above the recommended limits. Global surveys find that sub-Saharan Africa is the region with the highest levels of aflatoxins.

Livestock are exposed to aflatoxin through contaminated feeds. Pasture, hay, straw, and silage are prone to contamination with aflatoxin, but the levels are low. The major source of aflatoxin ingested by animals comes from commercially formulated feeds. The feed ingredients maize, wheat, and oil cakes are commonly contaminated and are the major source of aflatoxin exposure of animal feeds.

The most effective way of reducing aflatoxins in feed and food is to control, prevent, or minimize contamination at the point of production. Where feed is contaminated, low-cost and low-technology strategies are needed. In some countries, ammonization is used to decontaminate feeds. Aflatoxin binders are widely applied in all the EAC partner states by feed producers, although they are not registered for use as such. Their efficacy for the indigenous production and industry context is unknown. Research on their use is necessary, as it will help inform legislative and regulatory direction as it pertains to their safe and appropriate commercial use. Blending contaminated feed can reduce the level of toxins, but is also not legal in many countries. Increasing protein and vitamins in feed is palliative. This is also true of providing exercise, good environmental conditions, and reducing other stressors on livestock and fish.

Livestock production in the East Africa region is still undergoing development, with impressive growth rates and significant contribution to the gross domestic product of the states. However, although livestock numbers are many and growing, production is low. Among the countries with better production, Kenya averages about 1,600 kg per cow per lactation year-- still low as compared to countries like South Africa, with 2,500 kg per cow year.

Appendix 1 discusses constraints to livestock development and production, including but not limited to, pasture quality and availability, low-potential breeds, overpriced commercial feeds, diseases, poor nutrition, and an unstable market for liquid milk. This sets the context for discussion of aflatoxin in animal feeds and milk in the EAC. Policy changes should address breed upgrading, feed and fodder, and specific cereals for livestock development, and actions to achieve export growth intraregional and globally, as well as measures to stabilize the market for liquid milk, all of which can spur further growth in the sector.

Because the issue of aflatoxin contamination of animal feed is so complex, we have included specific findings and recommendations in multiple sections of this paper, with overarching policy recommendations appearing at the end, under Policy Recommendations. The Apendices also include detailed data on the susceptibility of different livestock types to aflatoxin poisoning; a detauiled description of current constraints to animal health and product processing across the EAC based on our field surveys and interviews; information on other mycotoxins which interact with and exacerbate the effects of aflatoxin ingestion; and suggested further readings.

Data for all categories and topics considered in this report was not fully available for all five of the EAC partner states. Where no data is reported from a particular country in a particular section of this report, please assume that our literature reviews and interviews were not able to source any.

Because the issue of aflatoxin contamination of animal feed is so complex, we have included specific findings and recommendations in each section of this paper. Overarching policy recommendations appear at the end. We have also prepared an appendix that includes detailed data in tabular format on the susceptibility of different livestock types to aflatoxin poisoning, and data in tabular format resulting from our study of the constraints to animal health and product processing across the EAC. Finally, we have included appendices on other mycotoxins that interact with and exacerbate the effects of aflatoxin ingestion, plus suggested further readings.

Please note that data was not available for all topics from all five of the EAC partner states. Where data is lacking from a particular country on a specific topic, the reader may assume that neither our literature reviews nor interviews generated any information.

Introduction

Livestock in Africa suffer from very high burdens of sickness and death and also have low productivity compared to other regions. While the exact role aflatoxins play in contributing to this problem requires additional research, infectious disease and malnutrition are probably the most important causes of livestock death. Lack of nutritious feed and lack of genetic potential for high production are probably the most important causes of low livestock productivity. Nevertheless, aflatoxins certainly contribute to some extent.

Numerous studies on African livestock indicate annual mortality is high. A literature review found annual livestock mortality varies from 6 percent to 28 percent across all species and age groups, with around 25 percent of young animals dying each year (Otte and Chilona2002). Annual mortality of backyard poultry is 30 percent to 80 percent. The majority of this loss is due to infectious disease, with malnutrition a secondary cause (Grace et al. 2012). There are no studies on the impacts of aflatoxins on livestock disease, but most studies on feed and animal source foods show high levels. This suggests that aflatoxin is contributing to the current burden of livestock disease.

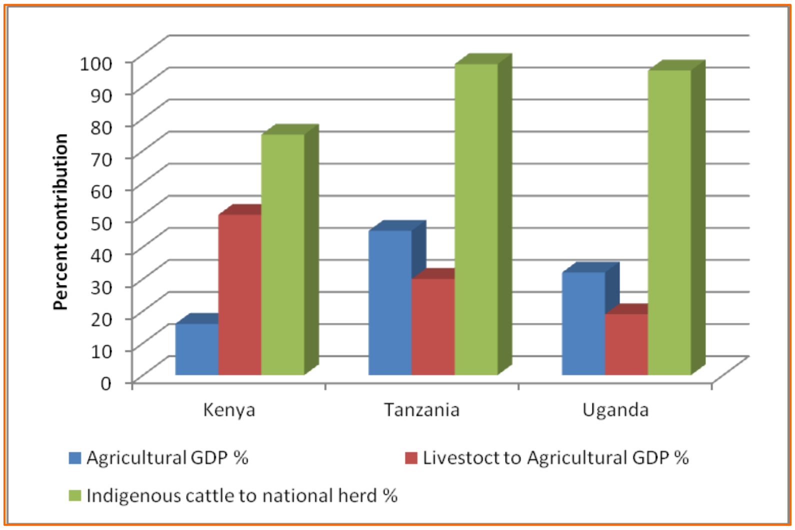
Numerous studies show that the productivity of African livestock is low by global standards. Much of this productivity gap is attributable to inadequate feed and to genetics that are not optimized for high productivity.

There are few studies on health impacts of mycotoxins in livestock in Africa. Some factors are likely to increase risk: aflatoxins in feed are largely uncontrolled; agricultural practices and environmental factors foster the growth of mold; heavily contaminated food is fed to livestock; livestock are stressed by inadequate nutrition and other health problems. On the other hand, some factors are present that are likely to reduce risk: few animals are given concentrate feed; levels of concentrate feeding are low; production is low; animals are not highly selected and animals are slow growing.

Livestock Production and Consumption in the EAC

Livestock Overview for the EAC

Livestock plays an important role in the economies of the East African countries. Livestock are kept either in pastoral areas or smallholder dairy farms under semi- or intensive farming systems. Pastoral areas contribute between 10 and 44 percent of the Gross Domestic Product (GDP) of African countries. An estimated 1.3 billion people benefit from the livestock value chain. Pastoralism directly supports an estimated 20 million people, the total annual milk, provides 90 percent of the meat consumed in East Africa, and contributes 13 percent, and 8 percent of GDP in Kenya, and Uganda, respectively (IRIN AFRICA 2013). Figure 1 shows the relative contribution of pastoralism to the national economies of Kenya, Uganda, and Tanzania. At the time of this report, no data was available for Rwanda and Burundi.



Source: Fact Sheet: Eastern African Pastoralism/ists, 2010

Figure 1: Economic contribution of pastoralism in Kenya, Tanzania, and Uganda.

The importance of livestock is underscored by the new revaluation of the sector contribution to national GDP. In the four countries evaluated by the Inter-Governmental Authority on Development (IGAD), (of which two fall within the East African Community (EAC) Kenya, Ethiopia, Uganda, and Sudan, the estimated values increased from $16.68 to $22.84 billion dollars, a 37 percent increase in the regional contribution to the GDP. Kenya had the largest increase of 150 percent (IGAD 2013). Table 1shows the livestock contribution to national GDP by country derived by IGAD.

Table 1: Contribution of livestock to GDP, 2009 in billion U.S. dollars.

	Kenya	Ethiopia	Uganda	Sudan	Regional
Official value added	1.651	2.511	0.282	12.236	16.68
Re-estimated value added	4.124	3.998	0.527	14.525	22.844
Percentage increase on official estimate	150 percent	59 percent	87 percent	19 percent	37 percent

The term livestock in this report refers specifically to dairy and beef cattle, poultry (mainly chickens)--the livestock for which aflatoxin is an important issue. In the case of cattle, the main concern is transfer of aflatoxin to milk. In the case of pigs and poultry, the concerns are negative health impact and reduced production due to chronic exposure, because their feeds contain more of the cereals and oilseeds prone to aflatoxin contamination. Data on the populations of these species shows the importance of this sector and the need to manage aflatoxin exposure as this would affect their health and production. The cattle population in the EAC states is estimated at 137.3 million heads (FAOSTAT 2012). Milk production and milk producing animals are as shown by country in Table 2. The chicken and pig populations are shown in Table 3. The population of chickens (in 1,000 heads) is estimated at 112,960; the pig population is estimated at 11.5 million heads (Table 3).

Table 2: Cattle population and milk production in East Africa.

Country	Cattle (head)	Dairy cows (head)	Improved breeds	Milk production (tons)
Burundi	695,724	90,000		318,000
Kenya	19.3 million	5.7 million	3,739,161[a]	3,732,960
Rwanda	1.1 million	284,000	162,413 [d]	186,000
Tanzania	21.3 million	6.9 million	720,000[b]	1,207,500
Uganda	12.8 million	3.5 million	912,700[c]	1,853,099

Source: FAOSTAT, 2012
***This includes indigenous and improved breeds. [a]MoALFD, 2012; [b] TDB report 2013; [c]livestock census 2008* and [d] EADD, 2008.**

Table 3: Chicken and pig population in East Africa.

Country	Chickens/1000head	Pigs (head)
Burundi	2,835	377,038
Kenya	32,865	354,600
Rwanda	4,688	989,316
Tanzania	35,000	500,000
Uganda	37,572	2.4 million

Source: FAOSTAT 2012

Dairy and Poultry Sectors

Dairy Sector

The dairy sector in the EAC is varied and growing. In Kenya, it is dominated by an estimated 1.8 million smallholder dairy farmers (SDP Brief 7) contributing over 80 percent of the milk production in the country (IFC 2007). Average milk production has been estimated by FAO to be 564 kg/cow/lactation. The annual growth rate in the milk production has been estimated at 8 percent (EADD 2008).

In Tanzania, annual milk production is estimated at 1.64 billion liters; about 60 percent is produced by indigenous cattle kept in rural areas and 40 percent by improved cattle kept principally by smallholder producers. There are significant differences in milk production between indigenous and improved dairy cows, producing 1-2 liters as compared to 7-10 liters per cow per day respectively. At present, about 10 percent of Tanzanian milk enters the market. Livestock contribution to GDP (Tanzania Economic Survey 2010) is 40 percent from beef, 30 percent from dairy, and the remaining 30 percent from other livestock commodities.

In Uganda, the dairy industry is estimated to contribute more than 50 percent of livestock GDP. The subsector has continued to grow at an average rate of 8-10 percent a year over the last 10 years (Uganda National Dairy Strategy 2011-2015). Total national milk production has been increasing steadily over the last two decades, from approximately 395 million liters in 1986 to an estimated 1.5 billion liters per year in 2008 (DDA 2008).

In Rwanda, livestock constituted just 2.2 percent of GDP on average between 2001 and 2006 and grew at an average annual growth rate, [Compound Annual Growth Rate (CAGR)] of 3.5 percent in the same period (EADD 2008). Milk production has continued to increase from 109.3 million liters in 2000 to 186.4 million liters in 2007 (EADD 2008) mainly due to the government programs to import exotic breeds and the "one cow per poor family" policy. Milk consumption is about 50 kg/capita per year.

Poultry Sector

In Kenya, poultry production is an important income-generating activity for rural smallholder families. Poultry contributes to the livelihoods of an estimated 21 million Kenyans. The estimated poultry population is 30 million birds. Of these, 22 million (76 percent) are free-ranging indigenous chickens (MoLD 2006). Feed accounts for a massive 70 percent of the cost of production in poultry ventures. Poultry numbers have grown on average by about 2.8 percent annually over the last 20 years, despite declines during the droughts of the early 1980s. Broilers and layers are estimated to make up 23 percent of the total Kenyan chicken population, with the number of broilers (13.4 percent) exceeding the number of layers (9.6 percent) (FAO 2000). Indigenous chickens lay about 100 eggs per year in clutches of 12-14 eggs (Kingori et al. 2010).

In Uganda, traditional poultry production systems are also based on free-ranging, indigenous chickens, kept widely among subsistence-level, rural households. In 2006, the estimated size of the national chicken flock was 23.5 million-- 3.7 million exotic/cross chickens and 19.8 million (84 percent) local/backyard chickens (Emuron et al. 2010). Free-range, local chickens account for 94 percent of the 27.8 million poultry in Tanzania (Msoffe 2002; MAFC 2008).

Milk Consumption

Milk consumption in the EAC partner states is estimated at 145kg, 53kg, 42 kg, and 38kg per capita in Kenya, Uganda, Tanzania, and Rwanda respectively (Kaitibie et al. 2008). In Uganda, production per cow ranges from 270 to 510 kg per year; in Kenya, production is between 2,500 and 3,500 kg per cow and year. Of the milk produced in Uganda, 30 percent is consumed at home and 70 percent is marketed. Of the marketed milk, 90 percent goes through the informal sector and 10 percent is processed (Uganda National Dairy Strategy 2011). In contrast, in Kenya, 80 percent of the milk is marketed through informal markets and 20 percent is sold through formal markets and is processed (EADD 2008). In Kenya, 80 percent of the milk is produced by smallholder dairy farmers, who are estimated to number 1.8 million (EADD 2008), constituting 35 percent of households.

Findings and Recommendations

Summarizing findings from these studies, we conclude:

- Impacts can be significant. For example, depending on the amount of aflatoxin in the diet and the length of the trial, chickens fed contaminated feed weighed from 38 percent to 97 percent less than birds fed normal diets. Layers given 10,000 ppb aflatoxin reduced their egg production by 70 percent (Huff et al. 1975). A review of multiple studies showed that mycotoxins in diets reduced pig weight gain by 21 percent (Andretta et al. 2011).
- In general, effects of aflatoxins are dose responsive: The higher the amount the greater the impact. In pigs, every extra 1000 ppb in pig feed was associated with a 3.9 percent extra decrease in weight (Andretta et al. 2011). In broilers, for every mg/kg (1000 ppb) increase of aflatoxin in the diet, the growth rate was reduced by 5 percent.
- In several trials, there is a threshold below which impacts are not seen. Some poultry trials showed no y weight reduction at levels between 50 and 800 ppb. Other trials, however, did show body weight reduction when chickens were fed between 75 ppb and 500 ppb. But all trials showed body weight reduction at over 1,000 ppb.

- Some studies show impacts in commercial herds and locks at levels below that shown to cause impacts in laboratory trials. This could be because animals are exposed to other stressors or they ingest a mixture of mycotoxins.
- Some studies show impacts at low levels of aflatoxins; others do not show impacts even at high levels. This could be due to other factors (food quality, exercise, breed, and age of animals) or to trials being too short or having too few animals to detect any clinical effects.
- Dietary levels of aflatoxin (in ppb) generally tolerated are: ≤50 in young poultry, ≤100 in adult poultry, ≤50 in weaned pigs, ≤200 in finishing pigs, <100 in calves, <300 in cattle and <100 in Nile tilapia. Dietary levels as low as 10–20 ppb may result in measurable metabolites of aflatoxin (aflatoxin M_1 and M_2) excreted in milk.
- However, ill effects may also be observed at lower levels, especially if animals are exposed to other stressors.
- The decrease in body weight due to aflatoxin exposure can be partially offset by exercise, protein, methionine, and good environmental conditions.

Aflatoxins in Animal Source Foods

Aflatoxins and their metabolites are present in animal source foods and deserve study in relation to the question of transmission of aflatoxin to the EAC human population from animal food products.

This is most important in the case of milk. Carry-over rates are much lower for meat and eggs; surveys in developing countries typically find levels in these products much lower than the permitted and recommended levels. Given relatively low quantities of animal source food consumed, meat and eggs are unlikely to present a major contribution to overall consumption of aflatoxin in the diet. Meat consumption may vary among different groups within a country, and although the average meat consumption in sub-Saharan Africa is increasing, it is still not projected to exceed 40 grams per capita a day before 2050 (Kearney 2010). As elsewhere, meat consumption within the EAC is increasing with income growth and urbanization (Rae 1998), so the relative contribution of meat is likely to be higher in wealthier and urban populations. However, the main risk of aflatoxin exposure would continue to come from cereals.

While levels of mycotoxins in cereals may reach thousands of ppb, levels in milk are generally much less than 100 ppb. However, aflatoxins in milk are of concern because milk consumption is often higher among infants and children, who are also more vulnerable. Accordingly, many countries set a lower threshold for aflatoxins in milk. For AFM1, maximum allowable levels range between 0.02 and 5 ppb, with 0.05 ppb the most common (Mohammadi 2011).

Most aflatoxins consumed by dairy cows are degraded by the microbial flora in the cow's rumen. Aflatoxins are also eliminated through urine and feces. However, a small amount of aflatoxin B_1 is metabolized to aflatoxin M_1 in the liver and excreted in the milk of dairy cows. The amount of aflatoxin M1 excreted in milk is only around 1-2 percent of the total amount of aflatoxins B_1 ingested (Fink-Gremmels 2008). This metabolite has been estimated to have around 3 percent of the mutagenicity of AFB (Cullen et al. 1987), however, it is still toxic, and its potential to inflict chronic disease has not been evaluated.

Higher-yielding animals consuming large amounts of feed concentrates typically show higher levels in their milk (up to 7 percent of the aflatoxin ingested). Some studies have indicated that mastitis may increase levels of aflatoxins, while other studies were unable to find such an association (Masoero et al. 2007).

Aflatoxins may also be present in sheep milk as well. One study found that dietary contamination by AFB1 near the European Union tolerance level (5 ppb) in complete feed for dairy animals resulted in an AFM1 milk concentration higher than the European Commission maximum tolerance level (Battaconeet et al. 2009)

Aflatoxins in Dairy Products

Aflatoxins are around three times higher in soft cheese and five times higher in hard cheese than the milk of origin. Paradoxically, however, using aflatoxin-contaminated milk for cheese production is risk mitigating. For example, if ten liters of milk makes one kilogram of cheese, and aflatoxin is five times higher in hard cheese, then the exposure of humans from aflatoxin by consuming one kilogram of cheese is half as much as the exposure from consuming ten liters of milk. Aflatoxin may also be present in yogurt and other dairy products. Recent studies have suggested that another toxic metabolite (aflatoxicol) may also be excreted in significant amounts in milk (Carvajal et al. 2003; Trucksess et al. 1983; this requires further research.

Aflatoxin in poultry feed can produce the metabolite aflatoxicol in eggs. Aflatoxins may be carried over from feed to eggs at ratios of 5,000-125,000:1 diet to egg ratio. (Zaghiniet al. 2005). The transfer of AFB1 from diet to eggs was studied in 12-week-old hens given diets containing 0, 100, 300 or 500 ppb AFB1 (Oliveira and others 2000). AFB1 was detected only at levels from 0.05 to 0.16 ppb (mean=10 ppb) in the eggs from hens on the 500 ppb diet. In this study, the transfer rate was 5,000:1 diet to egg ratio.

Aflatoxin in Milk and Eggs

Compared to aflatoxin in maize, wheat, and groundnuts, few studies have been carried out in East Africa to assess the problem of aflatoxin M1 in milk or eggs. Table 4 shows the results of these studies. The majority of these studies focus on urban milk samples; there are few from rural areas.

Transmission level of aflatoxin M1 in milk ranges from 1 percent-7 percent of the aflatoxin B1 found in the feeds (Grace 2013). No studies have been done to assess the amount of aflatoxin in eggs, although low levels have been reported elsewhere due to low transition from feed to eggs (Zaghini et al. 2005).

Aflatoxins in Meat and Offal

Trace levels of mycotoxins and their metabolites also migrate into the edible tissue of meat-producing animals. Feeding poultry 3,000 ppb may result in levels of 3 ppb in meat. Aflatoxin B_1 can be found in the liver of animals. In poultry, the highest concentrations are found in the kidney, gizzard, and liver (Wolzak et al. 1986). Studies in which birds were fed 0.25-3.31 mg/kg reported amounts of aflatoxins in tissues varying from 0 to 0.003 mg/kg (3 ppb).

In one trial, poultry were fed aflatoxin-contaminated feed for one week. However, after one week on an aflatoxin-free diet, aflatoxin residues could not be found in tissues (Wolzak et al.1986). Due to the rapid metabolism of aflatoxins in the body of a chicken (Hussain and others 2010), exposure to aflatoxins through consumption of chicken liver and meat is probably not a significant public health risk.

Aflatoxins in Processed Fish and Dried Meat

Processed fish has been found to be significantly contaminated with aflatoxins (Adebayo-Tayo et al. 2008) and may represent a risk. In eastern Nigeria, smoke-dried fish had AFB1 concentrations between 1.5-8.1ppb. Similarly, high levels were found in traditionally dried meat in Cameroon (Jones et al. 2004).Kilishi, a traditional West African dried meat, was found to have very high levels of aflatoxin (Jones et al. 2004). However, this was attributed to the use of pre-contaminated groundnut (35 percent of the ingredients), as mold growth levels in Kilishi were very low.

Mold-fermented foods such as fermented meat may also contain aflatoxins, but there is very little information on aflatoxins in traditionally processed foods.

Table 4: Aflatoxin M_1 in milk samples from Kenya, Tanzania, and Rwanda.

Country	Source of milk	percent positive	percent exceeding 50 ppb	Reference
Kenya	Urban farmers Nairobi (n=391)	45	22.3	Kang'ethe et al. 2007
	Urban farmers Nyeri (n=120)	60.8	3.	Kang'ethe and Lang'at 2009
	Urban farmers Nakuru (n=110)	77.3	10.3	Kang'ethe and Lang'at 2009
	Urban farmers Eldoret (n=107)	68.3	24.2	Kang'ethe and Lang'at 2009
	Urban farmers Machakos (n=99)	82.2	20.9	Kang'ethe and Lang'at 2009
	Rural farmers Makueni (n=210)	76.7	8.1	Kang'ethe, unpublished data
	Rural farmers Nandi (n=264)	51.9	0	Kang'ethe, unpublished data
Kenya	Rural market Makueni (n=25)	96	4.2	Kang'ethe unpublished data
	Urban market Nyeri (n=10)	100	3.0	Kang'ethe and Lang'at 2009
	Urban market Eldoret (n=18)	100	22.2	Kang'ethe and Lang'at 2009
	Urban market Nakuru (n=19)	100	36.8	Kang'ethe and Lang'at 2009
	Urban market Nairobi (n=100)	100	41.7	Kang'ethe and Lang'at 2009
	Urban market Machakos (n=18)	94.4	16.7	Kang'ethe and Lang'at 2009
Tanzania	Urban market Dar es Salaam (n=37)	92	24	Urio et al. 2006
Rwanda	Milk (UHT)(n=6)	Not detected		Personal communication (RBS2014)

Findings and Recommendations

- Risk assessment should be used to estimate the risks to human health disaggregated by age group and/or body weight associated with aflatoxins in milk and other animal source foods.
- Milk and traditionally dried/smoked foods (fish and meat) are likely to have highest levels of aflatoxin and so should be givenpriority attention.
- Withholding aflatoxin contaminated feed from livestock for 3-4 weeks before slaughter may be enough to clear toxins from muscle and organ meat.
- To ensure milk from dairy cows does not exceed limits, dairy feed should contain less aflatoxin than 50 times the limit. This may not be sufficient for sheep milk.

Aflatoxin Exposure Through Feed

Animals are exposed to aflatoxins through what they eat. The most contaminated animal feeds are maize, cottonseed, copra, and groundnuts (FAO 2008). In developing countries, a large proportion of food and feed are handled on the informal market, and animals are often fed crops that are considered unfit for human consumption because of mold, insect damage, or other problems. These crops are especially at risk for aflatoxin contamination. Animal feeds have an important role in enabling economic production of animal-source foods. Feeds may be produced in industrial feed mills or in simple on-farm mixers or by hand mixing.

Mycotoxin contamination in feed is a worldwide problem, although the relative importance of different mycotoxins differs by climate. One survey found that 30 percent of feed samples from Asian and Pacific countries tested positive for at least one type of toxin,while the result for Europe and the Mediterranean region was 52 percent (Binder et al. 2007). A study done on animal feeds in Africa (Rodrigues and others 2011) showed high levels in several African countries. This data is shown in Table 5.

Table 5: Aflatoxins in animal feeds in African countries.

Country	Number of samples	AF range (ppb)	AF average (ppb)
Algeria	14	0	0
Egypt	16	0-6	1
South Africa	77	0-7	2
Ghana	18	0-199	26
Kenya	27	0-556	52
Nigeria	50	0-435.9	115
Sudan	13	0-388	90

A large study by the animal nutrition company Biotin analyzed 4,023 samples for the most important mycotoxins in terms of agriculture and animal production: aflatoxins (Afla), zearalenone (ZEN), deoxynivalenol (DON), fumonisins (FUM), and ochratoxin A (OTA). Samples tested ranged from cereals such as corn, wheat, barley, and rice to processing by-products, namely soybean meal, corn gluten meal, dried distillers, grains with soluble (DDGS), and other fodder such as straw, silage, and finished feed. Of all the regions assessed, the highest proportion of contaminated products were found in Africa (80 percent positive).

Table 6 shows the contamination of maize, wheat, groundnuts, three staple foods in the EAC.

Table 6: Aflatoxin contamination of maize, wheat, and groundnuts.

Commodity	Country	Maximum Aflatoxin levels detected (ppb)	Reference
Wheat	Kenya	7	Muthomi et al. 2008
	Rwanda	<10	Personal communication (RBS 2014)
Maize	Kenya	354	Azziz-Baumgartner et al. 2005
	Kenya	>201	Lewis et al. 2005
	Kenya	136.4	Muthomi et al.
	Kenya	17	Alakonya et al. 2009
	Kenya	791	Probst et al. 2010
	Uganda	700	Kaaya 2011
	Uganda	1000	Kaaya & Warren 2005
	Tanzania	69.3	URT 1989
	Tanzania	158	Kimanya et al. 2008
	Tanzania	120	Manjula et al. 2009
	Tanzania	50	TFDA 2012
	Rwanda	> 20	Personal communication (RBS 2014)
Groundnuts	Uganda	2000	Kaaya 2011
	Kenya	4050	Mutegi 2010
	Tanzania	20	TFDA 2012
	Rwanda	<10	Personal communication (RBS 2014)

Source: Tanzania Food and Drug Authority (2012); Abt Associates, Inc.

A study in Nigeria on poultry feed found that levels of aflatoxin contamination ranged from 41,067 ppb (Ezekiel and others 2012). An average aflatoxin level of 109.68 ppb was found in animal feeds sampled in Sudan (Elzupir and others 2009). In Morogoro, Tanzania, 20 percent of maize bran, 25 percent of sunflower cakes, 30 percent of layer starter and finisher chickens and 67 percent of broiler starter and finisher chickens had aflatoxin levels above 20 ppb. The mean AFB1 levels in all the feeds was 21.5 ± 36.1 ppb; 169 out of 231 (73 percent) samples which were positive for AFB1 had levels >5 ppb (Kajunaet al. 2013). A total of 830 feed and 613 milk samples from four urban centers in Kenya were analysed for aflatoxin B_1. About 86 percent (353/412) of the feed samples tested positive for aflatoxin B_1, and 70 percent (248/352) had aflatoxin levels over the 5 ppb WHO/FAO limit for feeds destined for dairy animals (Kang'ethe and Lang'at 2009). In Uganda, aflatoxigenic *Aspergillus* spp. were detected in 83 percent of livestock and 67 percent of poultry feed samples (Sebunya and Yourtee 1990).

Types of Animal Feed: Roughages and Concentrates

Animal feeds can be categorized as roughages or concentrates. Roughages are feeds with a low density of nutrients and include most fresh and dried forages and fodders. Grass, silage, hay, legumes, cottonseed hulls, bagasse, and groundnut hay are examples of roughages. Concentrates are feeds with a high density of nutrients and low fiber. Concentrates may be fed as individual feeds or blended and formulated into balanced rations (compound feed).

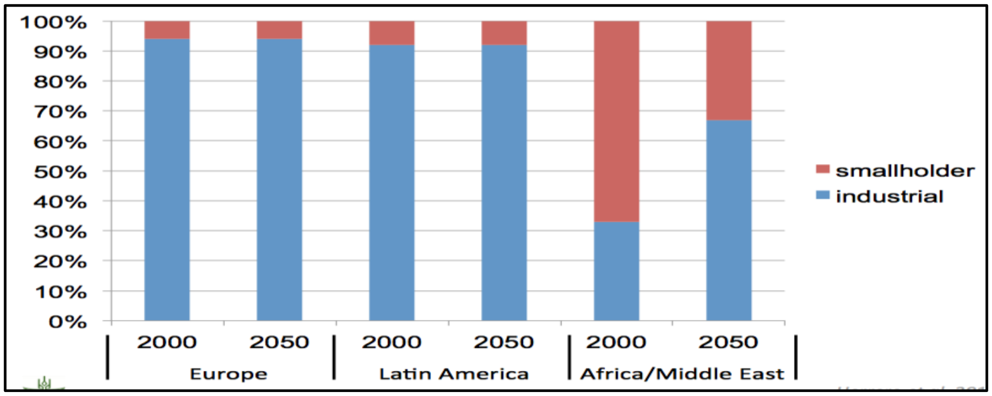
To assess the impact of aflatoxins on animal health, it is important to assess the level in the diet as a whole, rather than individual components. In addition, most feeds are contaminated with more than one kind of mycotoxin, and there might be both synergistic and additive effects of the mycotoxins which adds to the clinical impact of aflatoxins (Pier 1992). This complicates studies of the association between aflatoxin and the effect on animals.

Aflatoxins cannot be entirely avoided or eliminated from feeds by current agronomic and manufacturing processes and are considered unavoidable contaminants (Wood 1989). However, feeds vary considerably in their susceptibility to contamination.

- Maize, rice, barley, wheat, and sorghum are all susceptible to contamination with aflatoxins. Maize and rice are the most susceptible cereals. Groundnuts are highly susceptible and aflatoxins may be found in most oilseeds.
- Brewers' grains (byproducts from production of beer or other cereal-based alcoholic beverages) are commonly fed to animals and, because toxins are not degraded during fermentation and distillation, they may become concentrated in the byproduct. *Aspergillus* can also grow in brewers' grains.
- Animal by-products (meat meal and blood meal) may contain aflatoxin but levels are not likely to be high. Mycotoxins are usually not a problem in poultry litter as the pH inhibits mold growth.
- Pasture, hay, straw, and silage are more prone to contamination with other types of mycotoxins not considered in detail in this technical package. For more information, see the Appendix, Other Mycotoxins.

Feed Systems and Aflatoxins

Livestock in intensive systems is at higher risk of dietary exposure than animals in extensive systems. Worldwide, a high and increasing proportion of dairy cattle, poultry, and swine are kept in intensive systems, so aflatoxins are likely to be of increasing importance. By 2050, the majority of systems in Africa will be industrial. As aflatoxins are associated with concentrate feeding, this will aggravate the problem. The trend is shown in Figure 2.



Source: Herrero et al. 2014

Figure 2: Pig and poultry systems in 2000 and 2050.

But aflatoxin contamination of feed is already a concern. In Africa, most cattle keepers are smallholders who raise livestock and also practice crop farming both for household use and markets. Several studies in Kenya found that moldy and damaged maize is likely to be fed to livestock (Hoffmann et al. 2013). Not all moldy feed contains aflatoxins, and aflatoxins can be present even if feed appears normal. However, visibly moldy and damaged feed is more likely to contain aflatoxin.

Livestock Feeding

Milk production systems fall broadly into two categories: large scale and smallholder. Large scale production includes pastoral systems and intensive dairy production. Smallholder dairy production is practiced more widely in Kenya than other countries in the region, although this mode of production is increasing elsewhere as the demand for both land and milk rises. While the major source of aflatoxin contamination is compounded feeds, the bulk of dairy cattle feed is natural forage. This is especially true for non-exotic cattle, which constitute 70 percent, 93 percent, and 80 percent of the milking herd in Kenya, Burundi, and Tanzania respectively. Commercially produced compounded feeds are used mainly to supplement diets in the intensive dairy and by smallholder dairy farmers. In Kenya, dairy farmers usually buy formulated (ready mixed) feeds, while in Uganda and Tanzania, farmers mix the feed themselves. Poultry farmers, in contrast, rely almost exclusively on non-commercially formulated feeds for layers and broilers, in all countries. Poultry are more susceptible to aflatoxicosis than cattle.

Feed Production

Feed manufacturing is carried out by large and small enterprises across the region. The major feed manufacturers are Unga in Kenya, and Azam in Tanzania, Uganda, and Burundi.

The feed industry is most advanced in Kenya, with about 76 active members of the Association of Kenya Feed Manufacturers (AKEFEMA). Current production in Kenya of 500,000 tons per year (FAO 2011) falls below their operational capacity of 800,000 tons. In Tanzania, the volume of animal feeds manufactured per year is estimated at 800,000 tons, while demand is estimated at 2.5 million tons (MoLFD 2011). In Uganda, the annual production of compounded feeds by the commercial feed millers is estimated at 75,000 tons, with small-scale mixers producing 40,000 tons (Graffham et al. 2003).

Detection of Aflatoxins in Animal Feeds

Aflatoxins are difficult to detect because standards often require the detection of very low levels and because the toxins are not distributed evenly in food or feed. Protocols for sampling and analysis are available and should be used. Quality assurance and laboratory networks have an important role in ensuring accuracy of results. A number of tests are available--with differing costs, advantages, and disadvantages.

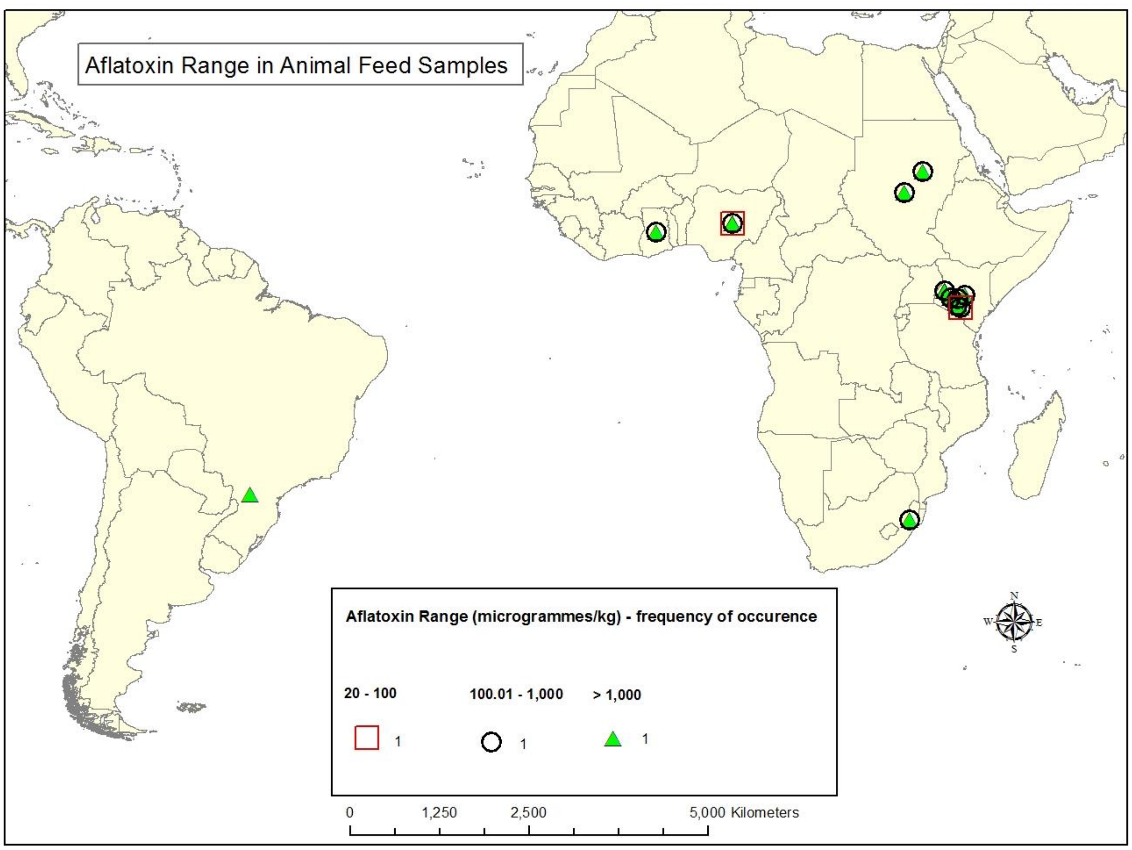


Figure 3: Aflatoxin tests of animal feeds.

Since mycotoxins can't be completely prevented in the crops, regulations are needed to prevent highly contaminated crops from entering the food chains. However, regulations are not enough. Also needed are reliable and affordable tests for aflatoxins, incentives for complying with regulations, and systems to deal with the contaminated products. Testing for aflatoxins is considered in more depth in the technical package on standards for animal feeds.

Generally, the difficulty of obtaining a representative sample is recognized as the major cause of inaccuracy in aflatoxin testing. However, laboratories and laboratory methods. vary, too. Most methods require a correct extraction and clean-up of samples; how this is done may affect the outcome (Turner, Subrahmanyam, and Piletsky 2009).

Highly reliable methods include liquid chromatography mass spectroscopy (LC/MS) and high (or ultra-high) performance liquid chromatography (HPLC); these often serve as references for other methods. Various immunoassays have also been developed, such as enzyme-linked immunosorbent assays (ELISA), which are easy and cost effective (Turner, Subrahmanyam, and Piletsky 2009; Pitt et al. 2012). A number of rapid tests provide a result over or under a certain limit. These may be used directly at the location of millers and producers, or in markets (Pitt et al. 2012).

Due to the difficulties in assessing mycotoxin levels, it is important to have a reference system where local labs can be accredited and ring tests performed, both within a country and in a region. By these means, the reliability of laboratory results can be established.

Findings and Recommendations

The data in this section suggest these recommendations:

- Most animal feed in Africa contains aflatoxin, and global surveys find higher levels of aflatoxins in commodities in Africa than in other regions.
- There should be standards for animal feeds, and a monitoring system.
- Binders should be considered to decrease the exposure in animals.
- Concentrates may include many different ingredients. It is important to assess the level of aflatoxins in the total diet rather than individual items.
- Aflatoxins cannot be entirely avoided or eliminated in feeds by current agronomic and manufacturing processes and should be considered unavoidable contaminants.
- Feeds and feed components vary greatly in their susceptibility to aflatoxin contamination. High-risk feeds require more attention. These include maize, oilseeds, groundnut, and commercial concentrate mixes.
- Both intensive commercial farms and smallholder producers are at risk from aflatoxins.
- Currently, most livestock production in East Africa is by smallholders using home-produced or home-mixed feeds, posing many challenges to feed safety.
- A coordinated, regional aflatoxin monitoring system for animal feed is needed.

Costs of Aflatoxin Contamination

Producers

Aflatoxin contamination leads to economic losses for the producer through reduced milk and egg sales, plus the longer time taken by animals to reach market weight (a longer time to feed them), higher costs of disease management (drugs and veterinary care), and higher morbidity rates.

Consumers

While regulation of aflatoxin in the food supply is largely absent across the region, consumers of animal source foods nevertheless also bear costs from aflatoxin contamination in animal products. This is especially true for infants and young children, who are large consumers of milk and whose health status can be dramatically affected by excessive aflatoxin exposure in their diets. Overall, consumers will continue to pay higher prices to compensate farmers for production losses and limitations associated with aflatoxin in the feed supply.

Governments

When countries apply stringent standards for low levels of aflatoxin in animal source and other foods, this results in losses of market share and foreign exchange for the exporting country. Otsuki et al. (2001) estimated that the European Union's strict aflatoxin standards would cause Africa an annual $670 million loss in trade, as compared to a $250 million in increased trade if the European Union applied the standards of the FAO/ WHO Codex Alimentarius Commission (Codex). Current estimates of losses are likely to be significantly higher for 2014. For example, since the standard for groundnuts of 5 ppb has been implemented by the EU, trade in this commodity between Africa and the EU has virtually come to a halt.

About 4.5 billion people globally are estimated to be chronically exposed to aflatoxin (Williams et al. 2004). This exposure entails high costs due to mortality (cost of productive capacity lost with premature death), morbidity (loss of productivity, hospitalization, and costs of health care public or private), and intangible costs of pain, suffering, anxiety, and reduction of quality of life (Coulibaly et al. 2008). Governments, to counter these losses, would have to invest in surveillance programs to predict and control the outbreaks and thereby incur costs for training, extension services, and outreach.

Industry Standards

Industry leaders interviewed during our field surveys (KDB, TAMPA, TAMPRODA, AKEFEMA) indicated that there are no industry standards by which feed prodcuers and farmers can self-regulate. Exacerbating this void are weak organizations of industry players. For instance, AKEFEMA once had a membership base of 112, but currently only 76 are active in the register. If industry is to assume a key role in the voluntary compliance and self-regulation to control feed quality, all players must belong to industry associations. This can only be reinforced by a government requirement that producers obtain an association certificate concurrent to registration of business. With strengthened industry associations, self-regulation is possible and could be effective. Government must lead the process through dairy boards and food and feed safety associations. These must be empowered by law to institute the changes by providing regulations in consultation with the stakeholders. Lastly, there must be firm oversight of practices that reflect adherence to the regulations.

Quality Requirements for Milk

The development of regionally harmonized and national quality standards for milk, animal products, and animal feeds produced within the EAC continues to lag due to the fragmentation of responsibilities between government departments and lack of adequate financial support for this process.

Imported milk and milk products are to conform to the harmonized East African standard on milk (US EAS 67:2006). However, this standard is for raw milk and many countries import mostly powdered and/or processed liquid milk. Codex maintains international standards for aflatoxin in milk and milk products.

Economic Losses From Aflatoxins in Livestock Feed

There are few studies quantifying the economic loss associated with aflatoxins and livestock in the EAC. Given that animal feeds are typically co-contaminated with several mycotoxins, and the variety of different genetics, ages, species, and management practices at farm level, it may be hard to disaggregate and estimate its impact. However, as livestock production increases across Africa, especially under intensive and semi-intensive systems, and these systems tend to use concentrates, aflatoxin-related impacts are likely to rise. Chronic aflatoxin exposure in livestock certainly has a larger impact on livestock production than acute aflatoxicosis. The impact on trade both within countries and in the region has yet to be quantified. The impact of aflatoxin consumption and livestock production on food security in vulnerable regions and populations is also yet to be quantified. However, considering the levels of aflatoxins shown in different studies and the ubiquitous exposure in animals, aflatoxins probably cost the livestock sector in East Africa tens of millions of dollars each year--while adding aflatoxin exposure to humans.

The costs of mycotoxins in the feed chain include research, production practices, testing, and regulation enforcement to prevent the toxins from appearing in feed products of affected commodities. Mycotoxin losses result from 1) lowered animal production and any human toxicity attributable to the presence of the toxin, 2) the presence of the toxin in the affected commodity which lowers its market value, as well as 3) secondary effects on agriculture production and agricultural communities.

Although the effects of acute aflatoxicosis can be dramatic, the impact on production and thus economics are even higher for chronic exposure (Kolosova and Stroka 2011). However, it is often difficult to diagnose chronic mycotoxicosis due to the diffuse symptoms and the fact that feed commonly contains more than one kind of mycotoxin (Binder et al. 2007). This makes it difficult to estimate the true economic cost of aflatoxicosis.

Several estimates for the costs of mycotoxins have been made, but estimates do not always distinguish between livestock sector and other costs.

- The cost of aflatoxins to the poultry and pig sectors in Indonesia, Thailand, and the Philippines was estimated at 155.8 million Australian dollars (Lubulwa and Davis 1994).
- The major use of cottonseed is as animal feed. Over a 20-year period, producers in Arizona experienced $96 million in revenue losses or 10 percent of the total value, while Texas producers lost $7 million in one year (Abbas 2005).
- *Fusarium* toxins in animal feeds in the U.S. can total up to $20 million in a year without outbreaks, and up to $46 million in years with outbreaks of ear rot (Wu 2007).
- Annual economic costs of mycotoxins to the U.S. agricultural economy were estimated to average $1.4 billion (CAST 2003). In comparison, the U.S. produces about $100 billion worth of livestock and the same of crops each year.

For an individual producer, economic losses depend on the relative costs of feed, livestock products, and compliance; the levels of aflatoxin contamination; and other factors that either reduce or exacerbate the impact of aflatoxin.

Cost of Testing and Regulatory Enforcement

The economic cost of regulatory enforcement, testing, and quality control is also high. In the United States, the annual cost of regulatory enforcement, testing, and other quality control measures has been estimated at $466 million annually (CAST 2003).

In the U.S., a large turkey farm reported using 2,200 tests for aflatoxins at a cost of $2.67 each in order to ensure the safety of 400,000 tons of maize used as feed. The cost of testing corresponded to 1.8 percent of the value of the corn used (Abbas 2005).

Generally speaking, exporting countries are in favor of less stringent regulation for exported products, while importing countries prefer more stringent regulation. The presence of aflatoxin in feed or raw ingredients can result in inability to export. African countries export substantial amounts of feed ingredients but are relatively minor importers of compound feeds.

According to the Joint FAO/World Health Organization (WHO) Expert Committee on Food Additives (JECFA), the scientific body that develops advisory international standards on food additives and contaminants for the Codex, “Those delegations from countries in which aflatoxin contamination is a problem because of their climatic conditions naturally wish to have standards in which higher levels of contamination are permitted so that they can trade their products on world markets” (Dohlman 2003).

Findings and Recommendations

Summarizing findings from studies on the impacts of aflatoxin, we conclude:

- The effects of chronic aflatoxin exposure of livestock are more economically important than acute exposure.
- Mycotoxins are likely to cost African livestock sectors millions of dollars annually; however, detailed studies on economic costs are not available.
- Regulatory enforcement and quality assurance for aflatoxin management will have high costs and efforts should be made to pursue these effciecntly..
- Exporters of feed ingredients may favor less stringent regulations than importers.

Risk Assessment

Mandy different chemicals, toxins, and infectious agents can affect human health. Substances that can cause harm are called "hazards". When considering any potential hazard, decision makers wish to know, “Can this cause harm?” “What harm can it cause?” and “What can be done to manage the harm?” Risk assessment is the science-based process to answer these questions. Risk assessment is the gold standard method for assessing the risk to human health posed by aflatoxins in animal source foods.

The Codex provides detailed guidelines on prioritizing hazards in feeds (CAC/GL 81-2013). However, these methods rely on large amounts of information on hazards which is often not available.

Information required for risk assessment includes data on:

- Consumption of foods prone to contamination, by different groups of people
- Levels of toxins in the different foods
- Levels required for toxic effects in humans.

Table 7: Aflatoxins in livestock products in Africa.

Product	AFM_1 range	AFM_1 mean	AFB_1 Mean	Total AF range	Total AF Mean	Country	Study
Cow milk	2.04-4 ppb					Nigeria	Motawee and others 2009
Bulk milk	.22-6.9 ppb2.07ppb					Sudan	Elzupir and Elhussein, 2010
Baby food				1-20 ppb		Uganda	Ismail et al. 2008
Baby food	4.6-530ppb					Nigeria	Atandaet al. 2007
Buffalo milk	<0.010 - >0.25ppb					Egypt	Motawee and others 2009
Goat milk	<0.01 -0. 25 ppb					Egypt	Motawee and others 2009
Camel milk	<0.01 - 0.25 ppb					Egypt	Motawee and others 2009
Cheese	.16-.35 ppb	.21 ppb				Libya	(Elgerbi and others 2004)
Beef liver, fresh			.0714 ppb			Nigeria	Oyero and Oyefolu 2010
Beef kidney, fresh			.0435 ppb			Nigeria	Oyero and Oyefolu 2010
Beef, fresh			.01 ppb			Nigeria	Oyero and Oyefolu 2010
Beef heart, fresh			.0285 ppb			Nigeria	Oyero and Oyefolu 2010
Beef liver, dried			.0021 ppb			Nigeria	Oyero and Oyefolu 2010
Beef kidney, dried			.0348 ppb			Nigeria	Oyero and Oyefolu 2010
Beef, dried			.0013 ppb			Nigeria	Oyero and Oyefolu 2010
Beef heart, dried			.0143 ppb			Nigeria	Oyero and Oyefolu 2010
Beef, dried, "kilishi"			113.10 ppb			Cameroon	Jones and others 2004
Eggs					.82 ppb	Cameroon	Tchana et al 2010

Product	AFM_1 range	AFM_1 mean	AFB_1 Mean	Total AF range	Total AF Mean	Country	Study
Fish, Smoke-dried				1.5-8.1 ppb		Nigeria	Adebayo-Tayo, et al. 2008
Fish, fresh				22-70.5 ppb		Egypt	Hassan et al. 2011
Fish, salted				18.5-50 ppb		Egypt	Hassan et al. 2011
Fish, smoked				32-96 ppb		Egypt	Hassan et al. 2011

Findings and Recommendations

Studies on feed and animal-source foods in Africa show sufficient evidence that aflatoxins are a problem in the livestock sector. Further information is needed to determine the extent and trends, however. Studies should include:

- Prevalence surveys to assess the extent of feed contamination
- Epidemiological studies to measure the impact on animal health and productivity
- Risk assessment to estimate the danger posed to human health by aflatoxin residues in milk and other animal source foods.

Other recommendations include the following:

- Since different species and ages of animals differ widely in their susceptibility to aflatoxins, management and standards should be differentiated by species, age, and other relevant factors.
- Risk assessment should be used to estimate the risk associated with aflatoxins in milk and other animal source foods.
- There should be a harmonized risk assessment system in the region.
- Milk and traditionally dried or smoked foods have the highest levels of aflatoxin and so should be given the most attention.
- Withholding aflatoxin-contaminated feed from livestock for 3-4 weeks before slaughter may be enough to clear toxins from muscle and organ meat. This option merits further study.
- To ensure that milk from dairy cows does not exceed limits, dairy feed should contain less aflatoxin than 50 times the limit in milk.[1]

[1]This may not be sufficient for sheep milk, and more research may be needed to study the transmission of milk in goats and sheep.

Managing Aflatoxins in Animal Feeds

Management of aflatoxins in animal feeds requires:

- Good practices at producer, processor, and retail levels
- Appropriate, risk-based legislation and regulations
- Monitoring of aflatoxins in feeds and foods
- Appropriate management of contaminated feeds.

Good Agricultural Practices

Mycotoxin contamination of livestock feed can be controlled by several different measures. The most effective is to prevent mold infestation in crops, either pre- or postharvest. Though mycotoxins are not eliminated by most methods, they can be reduced significantly. A wide range of good agricultural practices (GAPs) have been developed to minimize aflatoxins. These include: use of resilient/resistant varieties; irrigation; fertilization; pest control; biological control using atoxigenic fungi; use of fungicides; harvesting under appropriate conditions; and, appropriate drying and storage. As these practices are not specific to livestock feed, they will not be considered in depth in this paper, however many are covered in considerable depth in the other 10 technical papers of this same series.

Good Practices for Livestock Feed

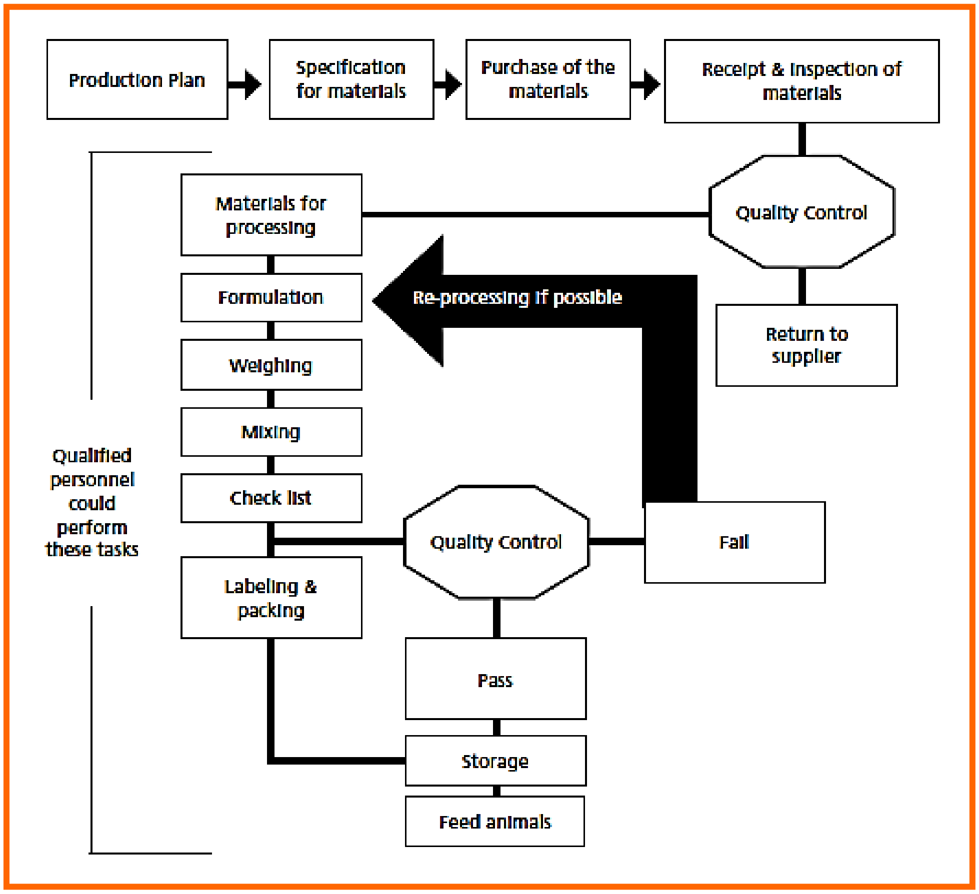
In 2004 the FAO/WHO Codex Alimentarius Commission approved a Code of Practice on Good Animal Feeding (CAC/RCP 54-2004). The code takes a risk-based approach to the entire food chain, providing detailed guidelines for production and use of feed. With the FAO, the International Feed Industry Federation has developed more detailed guidelines, which help to operationalize the Code of Practice on Good Animal Feeding. General principles include:

- Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs) and, if applicable, Hazard Analysis and Critical Control Point (HACCP) are used to control hazards in the feed production process.
- Feed ingredients are obtained from safe sources and subject to a risk analysis where the ingredients are derived from processes or technologies not evaluated.
- All feed and feed ingredients meet minimum safety standards such as those established by the Codex Alimentarius Commission.
- Labelling is clear and informative and in languages likely to be understood by users. It explains how to use feed and which animals it is intended for. Labelling indicates that the product has undergone aflatoxin testing.
- Traceability/product tracing of feed and feed ingredients, including additives, is enabled by proper record keeping for timely and effective withdrawal or recall of

products in case known or probable adverse effects on human or animal health are identified.

- The competent authority uses traceability/product tracing tools.
- There is a documented procedure for feed recall that ensures customers are informed promptly in the event of any irregularities.

International codes and guidelines also set out processes for manufacturing of feed on-farm. This process is described in Figure 4.



Source: Adapted from Avitech (FAO and IFIF 2010)

Figure 4: Manufacturing feed on-farm.

A number of codes and guidelines also exist at the national level. In South Africa, the Animal Feed Manufacturers Association (AFMA) published the "Code of practice for the control of mycotoxins in the production of animal feed for livestock," in June 2003. This provides an overview on mycotoxins; guidelines for establishing good practices for the control of mycotoxins in the feed industry; and interim guidelines on maximum acceptable levels of mycotoxins in animal feeds until local and/or internationally accepted regulations are established.

These codes and guidelines are appropriate for commercial feed manufacturers and large farms, but they are not well adapted to smallholders in East Africa. Simpler codes and guidelines that can be used by farmers and small-scale feed manufacturers are needed.

Appropriate Risk-Based Legislation and Regulation

Worldwide, aflatoxins are highly regulated. Many countries have regulations for the levels of mycotoxins allowed in animal feeds, and the most common regulations are for aflatoxins AFB1 or total aflatoxins (Kolosovaand and Stroka 2011). Since the impact of mycotoxins in livestock depends on the species, there may also be different levels permitted for different animals. Because of this, the U.S. Food and Drug Administration (FDA) has developed different permissible levels of aflatoxins depending on the animal species (FDA 2009). Within the European Union, limits also vary depending on the species, but the allowed limits are lower-- 5-50 ppb for AFB1 (Coker et al. 2000).

Principal considerations in drafting legislation on animal feeds include:

Feed and food security: Improvements in food and feed safety have direct and indirect benefits by improving health and productivity and reducing costs of illness (Caswell and Bach 2007). However, strict regulation may also cause food shortages and higher prices, harming the poor most. Therefore policy makers should keep food security in mind when setting food safety regulations. Efforts to mitigate food safety risks should not be adopted at the cost of sacrificing food supply or diverting resources from agricultural production (Cheng 2009).

Ability to comply: Stringent regulations may also provide incentives for producers and processors to evade regulations and thus create secondary markets where quality is even lower and regulation more difficult. Studies by the International Livestock Research Institute (ILRI) have found that currently between 40-80 percent of the food sold in East Africa does not comply with existing regulations. In these situations, a “ladder approach” is most useful. The ladder approach allows the majority of producers and traders who are not meeting standards to be assisted to meet standards in a progressive, incremental way.

Feed trade: Many feed ingredients are grown in tropical countries but have potential markets in developed countries. Studies on exports suggest that high standards in importing countries can impose high costs for exporters, even though the benefits of these high standards on animal or human health may be small. However, other studies on trade in animal products have found that meeting standards is a relatively less important barrier to exporting. Still others show benefits to exporters from meeting higher standards.

Harmonization: Different legislations, codes, and standards are a major source of trade conflict, and harmonized standards (such as the Codex Alimentarius), have been shown to increase trade. However, where countries have different priorities, or different capacity to enforce regulations, it may not be possible or useful to move too quickly to harmonize regulations.

Appropriateness: Legislation needs to fit the context. In the case of feeds, analysis is needed on the different types of producers and input providers, their different needs, and how the legislation may impact them. In East Africa, most farmers are smallholders; many farmers mix their own feeds or buy from small mills. Organic farmers and fair trade value chains may also need special consideration.

Coordination: In Africa, food safety is often the responsibility of multiple agencies and departments. It is important to align and coordinate food safety legislation across sectors (Pinstrup-Andersen 2012; Grace et al. 2011).

Monitoring of Aflatoxins in Feeds and Animal Source Foods

Because aflatoxins have negative impacts on the performance of livestock and can also contaminate meat and milk, producers and feed manufacturers have incentives to ensure that animal feed does not contain dangerous levels. In many countries, most monitoring of aflatoxin in feeds is carried out by the private sector, while the public sector oversees the process.

However, for small feed mills and small-scale farmers, the cost and complexity of monitoring aflatoxins is prohibitive at this time. Alternative and affordable testing and monitoring methodologies are needed.

Handling Contaminated Feed

When high aflatoxins levels are detected, the next problem becomes handling the contaminated products (Bagley 1979). In many countries, there are different strategies for this. The most important of these strategies, along with advantages, disadvantages, and costs are as follows.

Diversion from feed use: In countries like the U.S. where biofuel is a major consumer of maize, contaminated crops may be used for this purpose. Even though biofuel production may be one way to divert contaminated crops from the food market, mycotoxins are concentrated in the byproducts, requiring a safe disposal system. In the absense of such systems, mycotoxin-contaminated solubles that are important animal feed components, may still end up sold as commercial feed and cause production losses (Khatibi et al. 2014; Wu and Munkvold 2008).

Destruction: Highly contaminated cereals and feeds that cannot be safely used should be destroyed.

Sorting, trimming, and cleaning: Physical sorting can reduce contamination significantly: in some studies 40-80 percent reductions in aflatoxins were achieved (Park 2002).

Extrusion and heating: The greatest reduction in mycotoxin concentrations in extruded products seems to occur at temperatures greater than 160° C.

Binding: The addition of binding agents such as zeolite clays and alumina silicates is effective in reducing toxicity. Studies in the United States found that when zeolite clays were included in feed at a ratio of 200 parts feed to one part binding agent, they reduced most of the harmful effects of aflatoxins at levels of 1,000 ppb in pigs and 7,000 ppb for poultry. Their cost was around US$0.25 per ton of feed (Grace 2014).

Charcoal, yeasts, and alumina silicates are capable of binding mycotoxins and allowed in some countries to be used in feeds (Huwig et al. 2001). Although not common on a large-scale, global level, binding and detoxifying techniques are a promising way of using contaminated crops to increase the availability of safe foods.

Yeast derivatives such as glucomannans and mannan oligosacharides can increase growth in animals independent of aflatoxin levels, and can also reduce the pathogenic effects of the toxins (Aravind et al. 2003; Taklimi 2012; Ghahri et al. 2009; Hady et al. 2012). Humic acid has also been shown to reduce the toxic effects of aflatoxins (Ghahri et al. 2009; Taklimi 2012). Lactic acid bacteria are generally considered harmless food additives and used traditionally in fermented milk products, sourdough, and silage. Some strains have the ability to bind aflatoxins and may even prevent the fungi from creating toxins (El-Nezami et al. 1998; Pierides et al. 2014).

Blending: One method of reducing moderate levels of aflatoxin contamination is to blend contaminated grain with clean grain (blending 1 kilogram of grain with aflatoxin contamination five times above the limits with 9 kilograms of grain with no detectable aflatoxin would result in 10 kilograms of grain with aflatoxins at 50 percent of the permissible amount). Blending of contaminated crops has been practiced where highly contaminated crops are mixed with non-contaminated crops to produce a mix that has an average level below the legal limits. This is generally not allowed in the United States, since the feed would be considered adulterated, but has been allowed on exception during unusually contaminated harvests (Price, Lovell and McChesney 1993; Bagley 1979).

Ammoniation: Other interventions aim to detoxify the contaminated products (Bata 1999; Peltonen et al. 2001). Treatment with gaseous ammonium can reduce aflatoxin levels dramatically, and can make feed safe and tolerated by animals (Bagley 1979). Ammoniation is a safe and effective way to decontaminate aflatoxins; it has been used with success in many countries but is not legal in others. The average costs are 5-20 percent of the value of the commodity.

Gaseous ozonization: This method has been applied and shown to have beneficial effects on contaminated feed, especially on reducing AFB1 (Proctor et al. 2004). However, it is not in use commercially.

Nixtamilization: This is the traditional alkaline treatment of maize in Latin America. It can reduce toxicity and has potential for wider applications.

Experimental treatments: A large number of chemical, physical, and microbiological methods have shown promise under experimental conditions.

Palliative: If aflatoxin contaminated feed is given to livestock, then palliative measures can reduce some of the risk. Levels of protein in feed and vitamins A, D, E, K, and B should be increased as the toxin binds vitamins and affects protein synthesis. Exercise may help.

Flexible feeding of aflatoxin contaminated cereals to livestock: Flexible levels for feed means that highly contaminated crops can be diverted from sensitive species to animals that are less susceptible, but only up to a certain level. Feeding to appropriate livestock is probably the best use of most aflatoxin contaminated cereals, providing levels can be reduced to acceptable limits. There are no currently established levels at which aflatoxins can be guaranteed safe for livestock, but many animals, especially mature animals, can tolerate aflatoxins well. Indeed, many experimental studies do not show statistically significant effects of low levels of aflatoxins and there is a consistent pattern of fewer or no signs at lower doses of aflatoxins and increasing effects at higher doses. Moreover, there appear to be no scientific papers describing toxic effects of mycotoxin when present at very low levels (French Food Safety Agency [AFSSA] 2006). Growth depression associated with aflatoxins is affected by multiple factors such as species and age. Rats on high protein diets with 500 ppb aflatoxin had better growth than rats on low protein diets without aflatoxins. Depending on species, age, and length of trial, experiments have found no effects from aflatoxins at levels from 200 to 5,000 ppb and significant effects at levels from 20 to 10,000 ppb. Table 8 gives an example of how contaminated foods may be fed to livestock, in this case maize (FDA 2013).

Table 8: Guidelines for acceptable aflatoxin level in maize.

Animal	Feed	Aflatoxin level
Finishing beef cattle	Corn and peanut product	300 ppb
Beef cattle, swine or poultry	Cottonseed meal	300 ppb
Finishing swine of 100 lbs. or greater	Corn and peanut products	200 ppb
Breeding beef cattle, breeding swine, or mature poultry	Corn and peanut products	100 ppb

Source: http://www.fda.gov/ICECI/ComplianceManuals/CompliancePolicyGuidanceManual/ucm074703.htm

Optimally, interventions should be focused on different levels. The most effective way of reducing the mycotoxins in feed and food is to avoid, or minimize, the contamination in the crops. Various strategies have been developed for this, including drying techniques, addition of preservatives or treatments, breeding and genetically modifiying crops to be more resistant, and applying non-toxigenic strains of molds to the crops (Wu, Liu, and Bhatnagar 2008; Dorner and Lamb 2006; Magan and Aldred 2007). However, in spite of decades of research and new technologies, mycotoxin continues to contaminate crops, and most of the technologies available today remain unavailable to the poorest producers.

Therefore strategies to handle the contaminated crops must be developed for the East Africa context. Directing contaminated crops toward more resistant animals may be one way of diverting aflatoxin from the food chain. There are also promising binders that should be evaluated to see if they are affordable and suitable for livestock.

Findings and Recommendations

The data on management of aflatoxins in animal feeds suggests that:

- National and international codes and guidelines exist for feed manufacture. Regional guidelines should be based on these but adapted to the regional circumstances. Commercial feed manufacturers and large farmers should comply with these guidelines, but additional instruments are needed for small-scale farmers and feed producers.
- Voluntary codes of conduct should be accompanied by legal instruments to ensure compliance with appropriate standards.
- Highly contaminated feed or feed ingredients that cannot be safely used should be destroyed.
- Depending on levels of contamination, the use of blending, binders, decontamination, or flexible feeding may allow safe use of aflatoxins as livestock feed.

Policy Recommendations

The data and analyses in this report suggest the following policy and program related recommendations for the EAC.

1. As demand for animal source foods in the EAC will continue to rise as a result of urbanization and income growth, the livestock industry should be used as an opprtunnity to increase rural incomes and strengthen resilience and livelihoods.

2. A comprehensive set of policies and programs to support the development of forages, pasture, and specific cereal crops for animal feeds should be pursued across the region. These should address simultaneously address the threat of aflatoxin.

3. Given the economic and nutritional importance of animal products for the EAC partner states, , legislation, policies, regulations, and practices to develop an aflatoxin safe feed supply should be given high priority.

4. Countries should more accurately calculate the contribution of the livestock and fish subsectors of the GDP, which are grossly undervalued, to equitably budget funds for longer term development to realize the full economic and food security potential of the sector.

5. The EAC partner states should collaborate to undertake a detailed study covering all the agro-ecological zones, livestock and fish production systems, and seasonal factors to determine the magnitude of the aflatoxin problem in animal and fish feeds, animal products, and milk.

6. Based on the findings of this study, an action plan to address constraints and formulate solutions in the feed sector should be designed and implemented.

7. As the majority of the stakeholders have a very low awareness of the sources and effects of aflatoxin contamination, and of the tools available to mitigate contamination in feeds, animal and fish products, and milk, communicati0ons and awareness creation throuhgout the value chain should be the first step.

8. Harmonized aflatoxin standards for feed should be developed for the EAC partner states.

9. Regulations related to alternative uses of contaminated commodities as feed, such as the use of binders, blending, and decontamination technologies need to be included in the standards for feed development process based on scientific evidence.

10. Livestock development strategies (Livestock Sector Development Program 2011 Tanzania; Draft Livestock Policy 2008 Kenya) and the Common Africa Agricultural Development Programs (CAADP) should be updated to address the problem of aflatoxin.

11. Expedite the development of a multisectoral package of policies for the EAC states to guide aflatoxin management, affording due consideration to the importance of a safe and nutritious food and feed supply to ensure human and animal health, and sustainable economic growth across the East Africa region.

Appendix 1: Animal Species Affected by Aflatoxins

Table 9 shows the susceptibility of different animals to aflatoxins. The effects of aflatoxin depend on genetic factors (species, breed strain); physiological factors (age, nutrition, exercise); and environmental factors (climatic, husbandry, housing). Developing fetuses are very susceptible to even low levels, and young and fast-growing animals are more affected than adults. Males are more susceptible than females (Grace 2013).

One measurement of the toxicity of a poison is the LD50. This is the amount of toxin that will kill 50 percent of the animals exposed to it. Note: LD50 measurements are being phased out of toxicology because there are other tests more informative about the risk toxins pose to humans and LD50 is not considered acceptable on animal welfare grounds. However, this historic data provides an approximate yardstick of which animals are most vulnerable to aflatoxin (Hamilton 1986).

Because the lethal dose depends on body size as well as susceptibility, larger animals require a larger total dose. For example, sheep are more susceptible than chickens, but it takes 75 mg of aflatoxin per animal to kill half a group of sheep and only 16 mg of aflatoxin per animal to kill half a flock of chickens.

Table 9: Susceptibility of different animal species to aflatoxins.

Susceptibility	LD50 Dose	
High: Rabbits, ducks, cats, swine, rainbow trout	<1 mg per kg body weight	
Moderate: Dogs, horses, calves, turkeys, guinea pigs, sheep, baboon	1-2 mg per kg body weight	
Relatively resistant: Chickens, rats, macaque monkeys, mice, hamsters	5-10 mg per kg body weight	

Mammals

In mammals, the main organ targeted by aflatoxins is the liver. Aflatoxins have proven negative impacts on animal health which include:

- Death from poisoning if large amounts consumed (aflatoxicosis)

- Decrease in productivity when lower amounts consumed
- Cancers in some animals
- Immunosuppression predisposing to infectious diseases
- Vaccine failure due to inadequate immune response.

Economic impacts of aflatoxins include:

- Losses when livestock products exceed maximum ppb tolerance levels
- Losses when livestock feeds exceed maximum ppb tolerance levels
- Limitations on market entry due to failure to comply with standards
- Reduced nutritional quality of feeds due to molds and aflatoxin.

A 1982 study showed that dairy cattle are relatively resistant to aflatoxins, though calves are more susceptible than adult cows. However, significant decrease in milk production was seen when dairy cattle were fed 13 mg AFB1 per day for 7 days (around 400 ppb), compared to dairy cattle on an aflatoxin free diet (Applebaum et al. 1982). A 1979 study showed that a dairy herd exposed to contaminated maize (120 ppb) for several months had severe health problems including the birth of small and unhealthy calves, diarrhea, acute mastitis, respiratory problems, rectal prolapse, and hair loss. Milk production was decreased by 28 percent and breeding efficiency by 2 percent (Guthrie 1979).

Poultry

Many experimental studies have been carried out on chickens. Broilers are much more susceptible than layers. A meta-analysis of studies done on the effect of aflatoxins on growth performance found that for every mg/kg (1000 ppb) increase of aflatoxin in the diet, the growth rate in broilers would be reduced 5 percent (Dersjant-Li et al. 2003). In laying hens, aflatoxins are associated with reduction in egg production, egg weight, yolk weight, shell weight, and changes in yolk color.

In chickens, immune response can be impaired at levels that have no effect on growth rate (Pitt et al. 2012). Experimental studies found that exposing chickens to 200 ppb of aflatoxin in feed, and vaccinating them against Newcastle disease and two other common diseases, lowered their immune protection against subsequent experimental challenges (Gabal and Azzam 1998). The interaction of infectious bursal disease (IBD) and aflatoxicosis led to an increased mortality of 35.6 percent when compared to 3-21 percent in IBD alone and .03 percent mortality in aflatoxicosis (Omit et al 2005).

Aflatoxins have been associated with haemorrhagic anaemia syndrome in poultry, caused by consumption of moldy feed (Forgacs and Carll 1962). Productivity losses in commercial broiler operations can occur when aflatoxin concentrations were below those levels of concern established by controlled research in laboratory situations (Jones et al. 1982).

A study in South Africa found that broiler houses with poor growth and ascites had consistently higher levels of aflatoxin than samples from broiler houses without problems (18 ppb versus 9 ppb) (Westlake and Dutton1985).

Overall, studies find that aflatoxins reduce body weight, food conversion efficiency, average daily gain, and food conversion ratios. These studies are summarized in Table 10.

Table 10: Published studies on the impact of aflatoxins on chickens.

Animal	Aflatoxin dose and duration of experiment	Results	Study
Chickens (n=900)	0 (A), .3 (B), 1.25 (C), 2.0 (D) mg/kg for 28 days	Decrease in body weight and food intake. Increase in FCR (p<.001)	Bryden and others 1979
Broiler chicks (n=40-48)	0 (A), 5 (B) mg/kg feed, exercise (C), 5 mg/kg feed + exercise (D) for 24 days	Decrease in body weight in aflatoxin-treated group which can be partially improved by exercise [557.6 ± 9.3g (A), 542.7 ± 9.0g (B), 366.8 ± 7.4g (C), 412.5 ± 7.4g (D)]; increase in FCR in aflatoxin treated group [1.54 (A), 1.89 (C)]	Randall and Bird 1979
Layer chicks (n=40-48)	0 (A), 5 (B) mg/kg feed, exercise (C), 5 mg/kg feed + exercise (D) for 33 days	Decrease in body weight in aflatoxin-treated group, which can be partially improved by exercise [469.5±9.9g (B), 370.8±20.2g (C), 384.1±14.4g (D)]; Increase in FCR to aflatoxin treated group [1.59 (A), 1.75 (C)]	Randall and Bird 1979
Broiler chicks (N=40-48)	0 (A), 5 (B) mg/kg feed, exercise (C), 5 mg/kg feed + exercise (D)	Decrease in body weight in aflatoxin treated group, which can be partially improved by exercise [(510.5±12.5g (A), 502.0±12.0g (B), 414.9±19.8g (C), 434.0±8.1g (D)]; no difference in FCR	Randall and Bird 1979
Broiler chickens (n=75)	0 (A), .075 (B), .225 (C), and .675 (D) mg/kg feed for 7 weeks	Decrease in body weight in all aflatoxin-treated groups [2256±21g (A), 2098±26g (B), 1989±20 (C), 2047±24g (D)(p<.05)]	Doerr and others 1983
Broiler chickens (n=75)	0 (A), .3 (B), .9 (C) and 2.7 (D) mg/kg in feed for 7 weeks	Decrease in body weight in only 2.7 mg of aflatoxin per kg feed group [2024±30g (A), 1671±36g (D)] (p<.05)	Doerr and others 1983
1 day old broilers (n=70)	0 (A), .625 (B), 1.25 (C), 2.5 (D), 5.0 (E) and 10.0 (F) mg/kg in feed for 3 weeks	Aflatoxin dose-related decrease in body weight at the dose 1.25 mg/kg and higher [511±32 g (A), 463±16g (D), 386±25g (E), 286±13g (F)] and feed consumption [851±52g (A), 773±50g (D), 703±55g (E), 734±14g (F)], (p<.05)	Huff 1980
14 day old broiler chicks (n=200)	0 (A), 0.1 (B), 0.2 (C), 0.4 (D) or 0.8 (E) mg/kg AFB_1 for 35 days	No significant difference in weight gain (p<.05); Increase in FCR at the dose of 0.8 mg/kg [FCR; 2.02 (A), 2.11 (E)]	Giambrone and others 1985

Animal	Aflatoxin dose and duration of experiment	Results	Study
Male broiler chicks (n=180)	0 (A), 2.5 (B) mg/kg aflatoxin, and 2.5 mg/kg aflatoxin + 16 mg/kg of deoxynivalenol (C) for 3 weeks	Decrease in body weight [626±11g (A), 521±12g (B), 488±9g (C)]; weight gain]490±10g (A), 397±10g (B), 365±8g (C)]; protein serum levels [(2.9±.1g/100mL (A), 2.0±.1g/100mL (B), and 2.1±.1g/100mL (C)]; (p<.05)	Huff and others 1986
Day old chicks (n=120)	0 (A), 2.5 (B), 5.0 (C) and 10.0 (D) mg/kg in feed for 4 weeks	Aflatoxin dose related decrease in body weight (p>.05); [1.85±.03 kg (A), 1.57±.05g (B), 1.51±.04g (C), 1.47±.03g (D)]	Shukla and Pachauri 1985
1 day old broilers and layer chicks (n=40 each)	0 (A),1 (B), 4(C) mg/kg in feed for 4 weeks	Aflatoxin dose-depended decrease in body weights (p<.05). Broiler chicks: [332±17.81g (A), 254±14.35g (B), 239±13.5g (C)] Layer chicks: [158±3.6g (A), 139±4.41g (B), 126±5.82g (C)]	Ram and others 1988

Sheep and Goats

Sheep and goats are moderately susceptible to aflatoxin. A 2013 study showed that feeding sheep 1,750 ppb of aflatoxins for 3.5 years caused nasal and liver tumors in three out of eight sheep (Lewis et al. 1967). A study in Nigeria exposed West African dwarf goats to 0, 50,100, and 150 ppb of aflatoxin and found dose dependent decreases in weight gain, concentrate intake, feed conversion ratios and mortality (Ewuolaet al. 2013).These studies are shown in Table 11.

Table 11: Published studies on the impact of aflatoxins on sheep.

Animal	Aflatoxin dose and duration of experiment	Results	Study
Lambs (n=44)	0 mg aflatoxin in soybean meal (A), 0 mg aflatoxin in fish meal (B), 2.5 mg/kg diet soybean meal (C) or 2.5 mg/kg diet fish meal (D) for 35 days followed by 32 day wash-out period	Decrease in feed intake, daily gain in aflatoxin-fed lambs (p<.05) during treatment period and wash-out period. ADG: .53kg (A), .24 kg (C), .50 kg (B), .05 kg (D); ADFI: 4.19 kg (A), 2.74 kg (C), 4.05 kg (B), 1.7 kg (D); increase in FCR aflatoxin-fed lambs (p<.05); FCR: 7.6 (A), 11.2 (C), 7.6 (B), -45.5 (D)	Edrington and others 1994
Lambs (n=46)	23 lambs fed 2,500 ppb aflatoxins for 21 days (a), 13 lambs control (b)	Reduction in body weight 19.2 (a), 17 (b)	Ramos et al. 1996
Kids (n=20)	0 (A), 50 ppb (B), 100 ppb (C), 150 ppb (D) for 12 weeks	Final weight 11.5 kg (A), 9.9kg (B), 9.48kg (C), 9.1 kg (D)	Ewuolaet al. 2013

Turkey and Duck

Turkey and duck are highly susceptible to aflatoxins. Aflatoxins were in fact discovered after more than 100,000 turkey poults died in the United Kingdom, after being fed groundnuts imported from Brazil (Turkey X disease). Turkey X disease appears to have led to salmonellosis and candidiasis outbreaks (Siller and Osler 1961). In Zimbabwe, 70 ostriches died after being fed commercial pelleted feed. Samples found levels of 11, 55, 98, and 129 ppb of alflatoxin, suggesting that ostriches are more susceptible to aflatoxins than chickens (Siwela and Nziramasanga 1999). Quail are moderately resistant.

In one study, ducks and chickens were fed aflatoxin at 50, 100, and 200 ppb in their diet. Diets with 50 ppb and above significantly reduced body weight gain and utilization of dietary protein in ducks as compared with chickens. The higher the aflatoxin content above 50 ppb, the greater the difference in performance between ducks and chickens. Dietary aflatoxins caused liver damage in ducks while no damage was recorded in chickens (Ostrowski-Meissner 1986).

Quail seem more similar to chickens. In one experiment, laying quail were fed 25, 50, or 100 ppb of aflatoxin. Average weight and egg production were not affected but in groups receiving 50 ppb and above egg weight was lower, while liver lesions were seen at 200 ppb (Olivera et al. 2002).

Table 12: Published studies on the impact of aflatoxins on turkeys.

Animal	Aflatoxin dose and duration of experiment	Results	Study
14 day old turkeys (n=200)	0 (A), 0.1 (B),0.2 (C), 0.4 (D) or 800 (E) mg/kg AFB_1 for 35 days	Decrease in percent weight gain at the dose of 400 mg/kg and higher (averaged 5-week percent weight gain: 48.2 percent (A), 33.2 percent (D), 19.7 percent (E); Increase in FCR at the two highest doses [FCR averaged in 5 weeks: 1.81 (A), 1.89 (D); 2.28 (E)]; (p<.05)	Giambrone and others 1985

Pigs

Pigs are highly susceptible to aflatoxins. The most susceptible feed components and those used in commercially available pig feedstuffs are groundnuts, maize, and cottonseed. AFB1, AFG1, and AFM1 can be present in the sow's milk and different levels are possible depending on the initial contamination of the feed (Kanora and Maes 2009).

Many experimental studies have been carried out in pigs. A meta-analysis reviewed 85 articles published between 1968 and 2010, totalling 1,012 treatments and 13,196 animals. Mycotoxins resulted in a reduction in weight gain of 15 percent in females and 19 percent in males. The effects were greater in younger animals and at higher doses. For each additional 1,000 ppb of aflatoxin in the feed (1 mg per kg), there was a reduction of 3.9 percent in pig weight gain. Methionine and protein were protective (Andretta et al.2011). Another meta-analysis of studies done on the effect of aflatoxins on growth performance found that for every mg/kg increase of aflatoxin in the diet, the growth rate in pigs would be reduced 16 percent(Dersjant-Li et al. 2003). Additionally, dietary concentrations that would cause a 5 percent reduction in growth rate were estimated at 0.3 mg/kg for pigs.

Clinical signs of acute aflatoxicosis include anorexia, nervous signs, and sudden death (Kanora and Maes 2009). In America, unusually high levels of aflatoxins in maize were linked with salmonellosis in pigs (Miller et al. 1978). Experimental intoxications have shown damaged white blood cells in piglets, indicating a loss of immune-competence due to exposure of sows to aflatoxins.

Table 13: Published studies on the impact of aflatoxins on pigs.

Animal	Aflatoxin dose and duration of experiment	Results	Study
Pigs (n=50)	0 (A), 0.2 (B), 0.7 (C), 1.1. (D) mg/kg feed for 16 weeks	No significant difference in body weight between groups. Increase in FCR [4.53 (A), 4.55 (B), 4.67 (C), 4.76 (D)] ($p<.05$)	Armbrecht and others 1971
Pigs (n=60)	0 (A), 1.0 (B), 2.0 (C), 4.0 (D) mg/kg feed for 13 weeks	Increase in FCR (3.14 (A), 3.82 (B), 4.13 (C), NA (D)[a]($p<.001$)	Armbrecht and others 1971
Pigs, weanlings (n=110)	<0.002 (A), <0.008 (B), 0.051 (C), 0.105 (D), 0.233 (E) mg/kg feed for 120 days	No significant effect on weight gain or feed conversion	Keyl and Booth 1971
Pigs, weanlings (n=110)	<0.006 (A), 0.45 (B), 0. 615 (C), 0.81 (D) mg/kg feed for 120 days	Decrease in ADG at the dose of 615 and 810 µg/kg feed [0.71 kg (A), 0.60 kg (C), .47 kg (D)] ($p<.05$)	Keyl and Booth 1971
Pigs (n=32; 8 for each of 4 groups of pigs)	0.02 (A), 0.385 (B), 0.75 (C), 1.480 (D) mg/kg (control: 0.020mg/kg group)	Decrease in ADG (dose-related) [.77 kg (A), .67 kg (B), .57 kg (C), .41 kg (D)] and ADFI [2.87 kg (A), 2.53 kg (B), 2.15 kg (C), 1.61 kg (D)] ($p<.05$); Increase in FCR in the 1.480 mg/kg treated group [3.74 (A), 3.97 (D)] ($p<.05$)	Southern and Clawson 1979
Pigs, 5-6 week old (n=30; 10 each in control, 0.3 and 0.5 µg/kg groups)	0,0.3 and 0.5mg/kg feed for 10 weeks	Decrease in weight gain in both aflatoxin-treated groups up to 2 kg in 10-week period and feed consumption in high-dose group compared with controls ($p<.01$)	Panangala and others 1986
Pigs, weanlings (n=90)	0 (A),0.42 (B), 0.84 (C) mg/kg for 49 days	Decrease in ADG [.52 kg (A), .46 kg (B), .28 kg (C)] and ADFI (1.13 kg (A), [.95 kg (B), .67 kg (C)]; Increase in FCR [1.72 (A), 1.92 (B), 2.70 (C)] (linear $p<.01$ and quadratic $p<.05$)	Lindemann and others 1993
Pigs, weanlings (n=63)	0 (A), 0.8 (B) mg/kg feed for 42 days	Decrease in ADG [.64 kg (A), .41 kg (B) and ADFI (1.32 kg (A), .82 kg (B)]	Lindemann and others 1993
Pigs, weanlings(n=96)	0 (A), 0.992 (B) mg/kg feed for 6 weeks	Decrease in ADG](.505 kg (A), .392 kg (B) and ADFI (1.1 kg (A), .88 kg (B)] ($p<.01$)	Schell and others 1993a
Pigs, weaned (n=54)	0 (A), 0.88 (B) mg/kg feed for 4 weeks	Decrease in ADG [(.64 kg (A), .48 kg (B)] ($p<.05$) and ADFI [(1.32 kg (A), 1.0 kg (B)] ($p<.05$) Increase in FCR]	Schell and others 1993b

Animal	Aflatoxin dose and duration of experiment	Results	Study
		(2.08 (A), 2.43 (B)] (p<.05)	
Pigs, weaned (n=81)	0 (A), 0.5 (B) mg/kg feed for 5 weeks	Decrease in ADG [.66 kg (A), .46 kg (B)] and AFDI [(1.41 kg (A), .97 kg (B)] (p<.05)	Schell and others 1993b
Pigs, weaned (n=63)	0 (A),0.8 (B) mg/kg feed for 4 weeks	Decrease in ADG [.63 kg (A), .52 kg (B)] (p<.05) and ADFI [(1.29 kg (A)< 1.02 kg (B)] (p<.01)	Schell and others 1993b
Pigs, growing barrow **(n=40)**	0 (A), 3 (B) mg/kg feed[b] for 28 days	Decrease in weight gain [19.1±.73 kg (A), 10.7 ±1.06 kg (B)] (p<.05)	Harvey and others 1994
Pigs **(n=27)**	0 (A), 2.5 (B) mg aflatoxin/kg feed, 2.5 mg aflatoxin/kg feed + 2400 IU tocopherol (C) for 32 days	Decrease in bodyweight [38.4 ±3.9 kg (A), 22.0±2.0 kg (B), and 23.5±3.0 kg (C)] and feed consumption [138±20kg (A), 41±4.5 kg (B) and 45±2.0 kg (C)] (p<.05)	Harvey and others 1995b
Pigs **(n=18)**	0 (A), 2.5 (B) mg aflatoxin/kg, 2.5 mg aflatoxin + 100mg fumonisin B_1/kg feed (C) for 35 days	Decrease in bodyweight [(49.2 kg (A), 33.2 KG (B), 23.9 kg (C)]; weight gain [(31.6 kg (A), 15.8 kg (B), 6.3 kg (C)], and feed consumption per pen [153.7 kg (A), 89.0 kg (B), 42.7 kg (C)]	Harvey and others 1995a
Pigs, 4 week old weaned **(n=36)**	0 (A), 0.24 (B), 0.48 (C) mg/kg feed for 30 days	Decrease in ADG [489 ±18g (A), 453±12g (B), 326±17g (C)] (p<.05)	Marin and others 2002

Fish

Fish vary in susceptibility to aflatoxins. Rainbow trout are one of the most sensitive species to aflatoxins. Rainbow trout fed diets containing AFB1 at 0.4 ppb for 15 months had a 14 percent chance of developing tumors. Feeding rainbow trout a diet containing AFB1 at 20 ppb for 8 months resulted in 58 percent occurrence of liver tumors, and continued feeding for 12 months resulted in 83 percent incidence of tumors. The more resistant Channel catfish were fed a diet containing purified AFB1 at 10,000 ppb for 10 weeks; they exhibited decreased growth rates and moderate internal lesions (Jantrarotai and Lovell 1990). Nile tilapia is widely farmed in tropical and subtropical regions. There have been several studies on aflatoxins with variable results. A diet with 100 ppb for 10 weeks significantly reduced growth (El-Banna et al. 1992), yet a diet with 250 ppb led to no adverse effects (Tuan et al. 2002). More recent, larger, and longer term trials show no difference in weight gain at 85 ppb but significantly less weight gain at 245 ppb and above.

In the majority of aquatic organisms exposed to AFB1, the toxic signs of anorexia, yellowing of the body surface, weight loss, feed efficiency reduction, liver dysfunction, and histological damage are commonly observed (Santacroce et al. 2007).

Table 14: Published studies on the impact of aflatoxins on fish.

Animal	Aflatoxin dose and duration of experiment	Results	Study
Channel catfish (n=450)	0, 0.1,0.404, 2.154 or 10 10,000 mg/kg for 10 weeks	Decrease in weight gain in the 10,000 µg/kg group by 24 percent compared with the control (p<.05) (weight gain per fish in the highest dosed group = 60g compared with 80g in control group)	Jantrarotai and Lovell 1990
Nile tilapia (n=160)	0 (A), .94 (B), 1.88 (C), .375 (D), .752 (E), 1.50 (F), 3.0 (G) mg/kg diet 25 days following with basal diet for 50 days	Decrease in ADG and ADFI, but not FCR in 1.88 mg/kg group and higher ADG: 10.87-11.30g (A), 7.28g (C), 7.1g (D), 4.78 g (E), 3.25 g (F), 3.66 g (G); p<.01; ADFI: .143-160g (A), .115g (C), .116g (D), .711g (E), .052g (F), .048g (G); p<.01	Chavez-Sanchez and others 1994
Nile tilapia (n= 2000)	0 (A), .19 (B), .85 (C), .245 (D), .638 (E), .792 (F), 1.641 (G) mg/kg diet for 20 weeks	AFB1 led to dose-and duration-dependent aflatoxicosis. No effects during the first 10 weeks; by 20 weeks, diet with 245 µg AFB1/kg or higher reduced growth and induced hepatic disorder. AFB1 did not affect the survival rate. Residue detected in liver but not in edible flesh. Tilapia tolerant for AFB1 exposure up to 1.641 mg/kg during 20 weeks.	Deng et al. 2010

Honey bees

Honey bees are relatively resistant to aflatoxins but mildly affected at very high levels of contamination. One study found 1,000 ppb and 2,500 ppb diet of aflatoxin B1 did not have any apparent toxic effects on bees. A higher dose of 5,000 ppb caused less than 50 percent mortality after 72 hours. Doses of AFB1 above 1,000 ppb caused over 90 percent mortality in 72 hours (Niu et al. 2011).

Appendix: Constraints to Animal Health and Product Processing

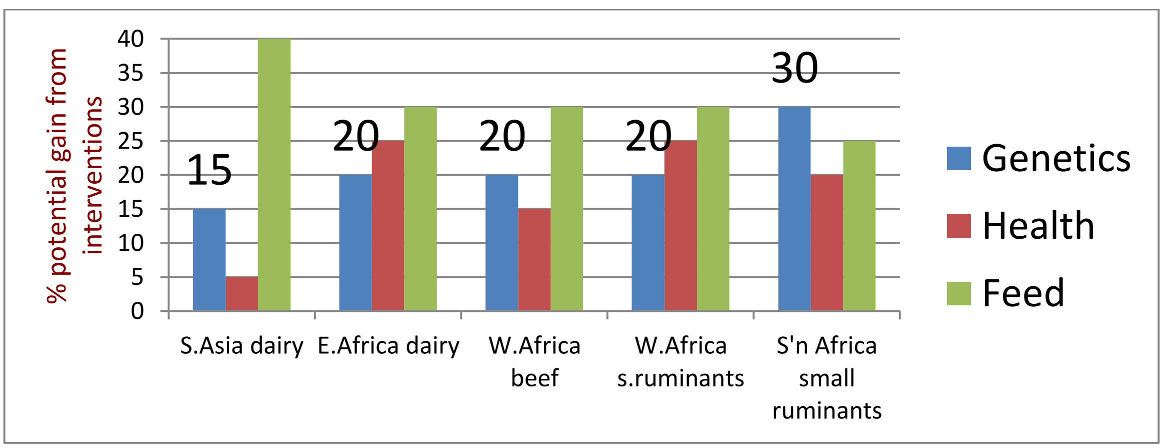
Table 15 summarizes the constraints to animal health and product processing; data was obtained through stakeholder interviews and a literature review for the East Africa region.

Table 15: Summary of constraints to animal health and product processing.

Production (regulators)	Feed manufacturing	Milk processing	Farmers
Burundi			
Small plots **Quality of pasture** **Diseases (ECF, FMD, NCD, ASF)** **Poor genetic pool** **Over fishing/lake pollution/small nets**	Markets for feeds High cost of raw materials	Poor observance of hygiene by farmers	Lack of forage areas Distance from farm land to establish pastures and forages Concentrates very expensive
Kenya			
Poor feeding and feeds **Poor genetic pool** **Local breeds** **Marketing structure not well organized**	Imposed VAT on raw materials Poor feed quality Poor surveillance on feed quality Insufficient local raw materials Lack of promotion of animal feeds' raw materials Poor raw materials	Declining milk production Costs of inputs high Farmers lack training in animal husbandry and nutrition Poor milk quality	Diseases (mastitis) Irregular heat High costs of inputs Low prices of milk
Tanzania mainland			
Poor genetic pool **Poor quality of feeds**	Poor raw materials Supply & accessibility Market for feeds/chicks Poor infrastructure Lack of testing facilities		Feed quality Costs of concentrates
Zanzibar (Tanzania island)			
Availability of feeds **No testing capacity** **Livestock not kept as a business** **Residues in milk (antibiotic, aflatoxins)** **Competent laboratory (personnel, infrastructure)** **Low fish feeds supply** **Inadequate fishing gear** **Inadequate seed fish**	Investment support from government Laboratory services for quality checking	Market access Poor handling of milk and fish	Poor quality feeds No laboratory services to check on feed quality Poor hatchability of the chicks Low knowledge on husbandry Low prices Lack of proper producer organization Poor quality pastures and small land

Production (regulators)	Feed manufacturing	Milk processing	Farmers
Uganda			
Diseases **Low genetic potential in breeds** **Inadequate knowledge of animal nutrition** **Fish feed production does not meet demand** **Seed supply inadequate**	Inadequate knowledge of animal nutrition by farmers Policy should have safety nets for feed manufacturers Poor quality and availability of raw materials Poor storage facilities for finished feeds and raw materials	Low milk supply in dry season Poor genetic pool, with low production capacity Very weak farmer institutions Lack of cold chain for milk Road network too weak to support collection of milk	Labor supply unstable Poor quality feeds Diseases Low market prices Unstable liquid milk market
Rwanda			
Nutrition **Disease control** **Low genetic potential of breeds**	No feed manufacturer interviewed as two new factories yet to be commissioned	Microbiological hygienic problems Antimicrobial residues	Unstable milk markets

Figure 5 summarizes sources of low yield in African livestock, indicating the extent to which genetics, feed, and health contribute to low productivity.



Source: Staal et al. 2009

Figure 5: Sources of low yield in livestock.

Appendix: Other Mycotoxins

Millions of poor smallholders depend on livestock for their livelihoods, and livestock production is the main supply of animal-source foods worldwide. Livestock productivity is hampered by many factors, especially in developing and tropical countries, such as infectious diseases and lack of adequate water and feed. Suboptimal harvesting of crops and storage contribute to increased infestations of mycotoxin-producing fungi, and mycotoxin contaminated products enter both the food and the feed markets. All species raised are susceptible to the negative health impacts caused by mycotoxins, but susceptibility differs between species and toxin. The main health impacts of the most important mycotoxins are listed in Table 16: Mycotoxins with important health impacts on livestock.

Table 16: Mycotoxins with important health impacts on livestock.

Mycotoxin	Main fungi	Impact on animal health	References
Aflatoxins	*Aspergillus* spp.	All livestock susceptible to different degrees Acute toxicity, hepatotoxic and nephrotoxic. Carcinogenic and mutagenic Growth impairment; immunosuppression	Coulombe 1993; Khlangwiset, Shephard, and Wu 2011; IARC 1993a and b; Richard 2007
Ochratoxin A	*Aspergillus* spp., *Penicillum* spp.	Nephrotoxic Immunosuppression Possibly carcinogenic	IARC 1993b; Bayman and Baker 2006; Richard 2007
Fumonisins	*Fusarium* spp.	Toxic to liver and central nervous system Possibly carcinogenic	IARC 1993b; Coulombe 1993; Richard 2007
Zearalenone		Swine highly sensitive, cattle less sensitive; endocrine disruption; Estrogenic effects, reduced reproduction, feminization, malformations	D'Mello, Placinta, and Macdonald 1997; Coulombe 1993; IARC 1993b; Richard 2007
Trichotecenes		Gastrointestinal disturbance; reduced feed intake; ill-thrift; immunosuppression	Coulombe 1993; D'Mello, Placinta, and Macdonald 1997; IARC 1993b; Richard 2007

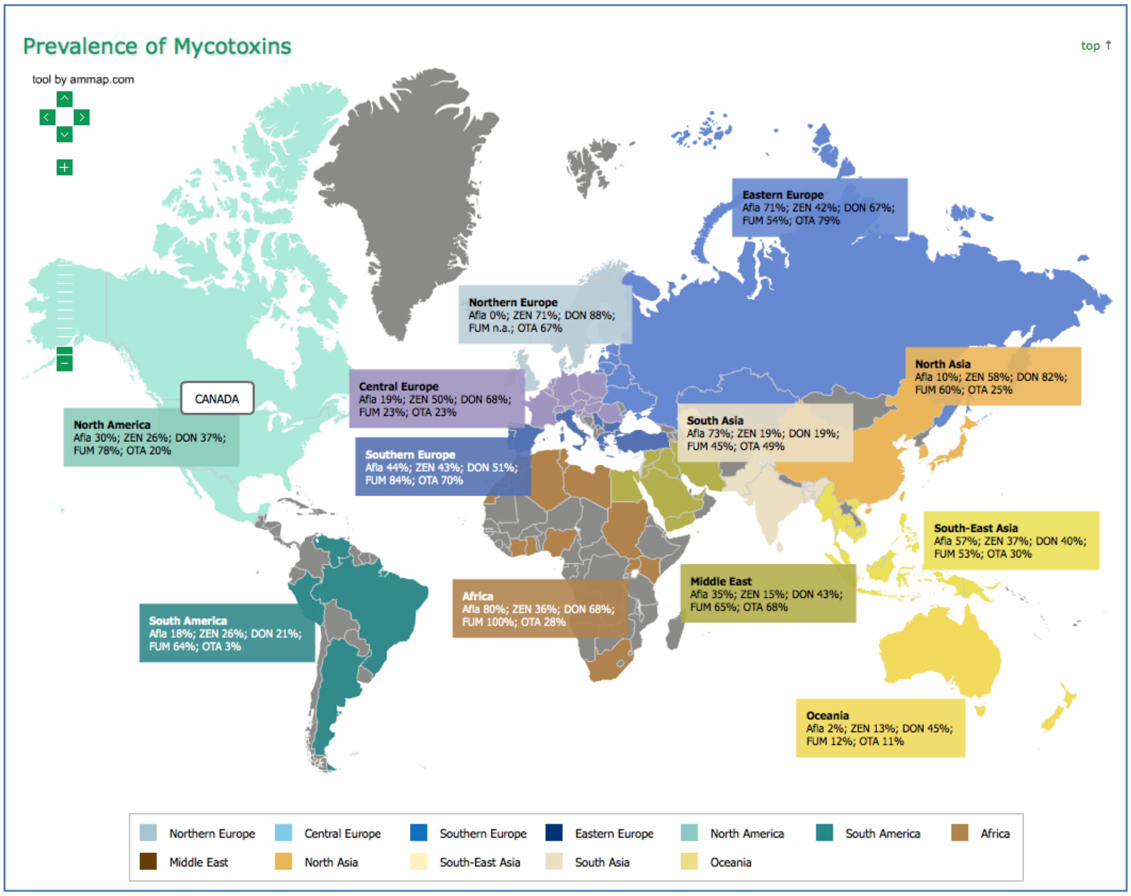


Figure 6: Global prevalence of mycotoxins by region.

Appendix: Further Reading

Aflatoxins: Finding Solutions for Improved Food Safety. Edited by Laurian Unnevehr and Delia Grace, International Food Policy Research Institute, Washington http://www.ifpri.org/publication/aflatoxins-finding-solutions-improved-food-safety

The nineteen briefs in this set provide perspectives on aflatoxin risks and solutions. They cover: 1) what is known about health risks from aflatoxins; 2) how to overcome market constraints to improved aflatoxin control; 3) the international policy context for taking action in developing countries; and (4) the state of research on new aflatoxin control technologies, including methods for aflatoxin detection, crop breeding, biological control, food storage and handling, and postharvest mitigation.

Improving Public Health through Mycotoxin Control, IARC Scientific Publication, No 158.http://apps.who.int/bookorders/anglais/detart1.jsp?codlan=1&codcol=73&codcch=158

This book aims to sensitize the international community to the mycotoxin problem in a format that is accessible to a wide audience and is useful to decision-makers across a broad spectrum of disciplines, including agriculture, public health, marketing, and economics. The book provides a scientific description of the occurrence and effects of mycotoxins and outlines approaches to reduce mycotoxin exposure.

Global Mapping of Aflatoxin Risk. Atherstone, C., Grace, D., Lindahl, J., Waliyar, F., and Osiru, M. 2014.Technical Report. Kampala, Uganda: ILRI.

This systematic literature review was undertaken to capture information on aflatoxin prevalence, risk factors, and control options and costs to support risk maps and evidence around costs and controls. Twenty-three (23) databases were searched using a combination of the Medical Subject Headings (MESH) terms from the National Institutes of Health National Library of Medicine. An initial 2500 papers were identified. After screening, 501 were retained for data extraction and included in this report and compiled into a prevalence database by region and commodity. The prevalence database was then converted into risk maps. GPS coordinates for the location of samples collected in each study included in the database were mapped and included in this report.

List of Abbreviations and Definitions

Term	Definition
A. flavus	*Aspergillus flavus*
AF	Aflatoxin
AFB1	Aflatoxin B1
AFM1	Aflatoxin M1
AFMA	Animal Feed Manufacturers Association
AFSSA	Agence Francaise de Securite Sanitaire des Aliments
AKEFEMA	Association of Kenya Feed Millers Association
ASF	African Swine Fever
CCP	critical control point
COMESA	Common Market for Eastern and Southern Africa
DDA	Dairy Development Authority
DON	deoxynivalenol
EAC	East African Community
ELISA	Enzyme-linked immuno-sorbent assay
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agricultural Organization Statistics
FDA	Food and Drug Administration
FMD	Foot and Mouth Disease
FUM	fumonisins
GAP	Good Agricultural Practice

Term	Definition
GDP	gross domestic product
GMP	Good Manufacturing Practice
HACCP	Hazard analysis and critical control points
HPLC	High (or ultra-high) performance liquid chromatography
IBD	infectious bursal disease
JECFA	WHO Joint Economic Committee on Food Additives
LD50	Lethal dose for 50 percent
LC/MS	Liquid chromatography mass spectroscopy
IGAD	Inter-Governmental Authority on Development
KDB	Kenya Dairy Board
MoALFD	Ministry of Agriculture, Livestock Fisheries development
MoLD	Ministry of Livestock Development
NCD	Newcastle disease
OTA	ochratoxin A
PACA	Partnership for Aflatoxin Control in Africa
ppb	parts per billion 1 ppb= 1 µg/kg = 1000 ppt
ppt	parts per trillion 1ppt= 1 ng/kg
RBS	Rwandan Bureau of Statistics
spp	species
SDP	Smallholder Dairy Project
TFDA	Tanzania Food and Drug Authority
Tanzania	Tanzanian mainland

Term	Definition
TAMPRODA	Tanzania Milk Producers Association
TDB	Tanzania Dairy Board
USD	U.S. dollar
VAT	Value-added tax
WHO	World Health Organization
Zanzibar	Islands of Zanzibar and Pemba
ZEN	Zearalenone

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