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*Review*

# Effects of aflatoxin contamination of grains in Ethiopia

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**This review was conducted to investigate the effect of aflatoxin contamination in Ethiopia. Risk of aflatoxin contamination of commodities in Africa, especially in Ethiopia is increasing. Aflatoxin can occur in a wide range of important commodities, including cereals, nuts, spices, figs and dried fruit. AFB1, AFB2, AFG1, AFG1, AFM1 and AFM2 are the most common type of aflatoxin. Aflatoxin contamination of agricultural commodities poses considerable risk to human and livestock health and economic losses. Exposure to aflatoxin leads to several health-related conditions in human including acute and chronic aflatoxicosis, immune suppression, liver cancer, liver cirrhosis, stunted growth in children and many others. In Ethiopia aflatoxins are detected from several crops especially from maize and groundnut. Several researches show that AFB1 is the most common aflatoxin in Ethiopia from most commodities at a very much higher level. AFM1 was also detected greater than the standard from milk and milk products in Ethiopia. This indicates that a lot of Ethiopian people are at danger of aflatoxin contamination. Lack of awareness on aflatoxin contamination increases the risk of damage to human and animals. High economic losses due to aflatoxin occur in the country crops and animals.**

**Keywords**: Aflatoxin, Ethiopia, health effect, liver cancer, economic loss.

## INTRODUCTION

Aflatoxins are toxic metabolites of Aspergillus fungi that can contaminate various food and feed products. Aflatoxins are the most common mycotoxins and even more potent mycotoxins. They are a type of mycotoxin produced by *Aspergillus* species of fungi, such as *A. flavus*, *A. parasiticus*, *A. nomius* and *A. nigur*. However, there are a number of Aspergillus species that produces aflatoxin, but in rare condition. Aflatoxins are largely associated with commodities produced in the tropics and subtropics, such as maize, rice, sorghum, barley, rye, wheat, groundnut, groundnut, soyabean and cottonseed (Burch and Rowsell, 2001). Aflatoxins can be found on a wide range of commodities including cereals, nuts, spices, figs and dried fruit. However, maize and groundnut are the two high aflatoxin risk crops in the world (Moss, 1998). These two crops play an important role in the diets of Ethiopian people. The infection of these crops by aflatoxicogenic fungi and hence contamination with aflatoxin is generally higher. Consequently, the exposure of human and animals to this toxin is higher and cause huge health and economic problems. *A. parasiticus* and *A. flavus* are common and widely distributed in tropical and sub-tropical parts of the world (Habtamu *et al*., 2001). Ethiopia as a tropical country has a high risk of aflatoxin contamination. Infestation of grains with Aspergillus species and aflatoxin contamination could occur before harvest and at storage.

Aflatoxins are acutely toxic, immunosuppressive, mutagenic, teratogenic and carcinogenic compounds targeting mainly the liver for toxicity and carcinogenicity (Peraica *et al*., 1999). The extent of damage by aflatoxin depends on the concentration of aflatoxin, way of exposure, the condition of the organism and others. After occurrence of aflatoxin injury it is difficult for treatment. However, it is possible to control aflatoxin contamination of grains by different management practices.

Aflatoxin contamination of grains causes several damages to human and animal health and economic losses. Ethiopia is favorable for the growth of aflatoxicogenic fungi and hence aflatoxin contamination of grains. Amare *et al*. (2006) examined 123 samples of maize products, of which 16 were positive with levels of 0.78µg/kg. Several studies also showed that liver diseases are increasing in Ethiopia and cause the death of many individuals. Most probably aflatoxin contamination is the common agent for this disease. Aflatoxin contamination of animal feeds, livestock and animal products like milk are also increasing in the country. Milk and milk products are infected due to the cows feed on aflatoxin contaminated feed. These indicate that the damage caused by aflatoxin in Ethiopia is increasing; this may be due to lack of awareness, lack of regulations, poor management and other. The quantitative study of aflatoxicogenic fungi and aflatoxin has been conducted by several authors in Ethiopia. Most of this report indicates that aflatoxin is increasing in the country and causes huge damage. In addition, lack of adequate information on status and effects of aflatoxin contamination leads to an enormous damage to the country. Therefore, the objective of this review is to address the effects of aflatoxin contamination of grains in Ethiopia.

**What are Aflaioxins?**

Aflatoxins are naturally occurring mycotoxins that are produced from *Aspergilus* species, predominantly from *A. flavus* and *A. parasiticus*. Thus, the toxin was named “aflatoxin” by virtue of its origin from *A. flavus* (Guo *et al*., 2008). This fungus was found in groundnut meal, which had been fed to different farm animals. The aflatoxin was first discovered in 1960 after contamination of turkeys in Britain when they were identified as toxic compounds of the fungus *Aspergillus flavus* and 100,000 turkeys died of the so-called ‘Turkey-X disease’ (Brase *et al*., 2013).
Aflatoxins belong to the class of mycotoxins and it is a group of approximately 20 related fungal metabolites generally produced by Aspergillus species, namely *A. flavus, A. parasiticus, A. ochraceoroseus, A. bombycis, A. nomius, A. fumigitus* and *A. pseudotamari* (Cheraghali *et al*., 2007). Aflatoxins are crystalline substances, freely soluble in moderately polar solvents such as chloroform, methanol and dimethyl sulfoxide, and dissolve in water to the extent of 10-20 mg/l. Aflatoxin naturally occurring fungal metabolite which is a highly stable compound and it can withstand normal food/feed processing procedures (PACA, 2013).

**Groups of Aflatoxin**

There have been identified 18 types of aflatoxins (Saleemullah *et al*., 2006; Strosnider *et al*., 2006). However, there are four most common naturally occurring aflatoxins B1, AFB2, AFG1 and AFG2 and a range of their active metabolites. According to Burch and Rowsell (2001) aflatoxin G1 and G2 are produced by *Aspergillus flavus* in groundnuts but are seldom found in maize. These names were given due to their blue (B) or green (G) fluorescence properties under ultraviolet light and their migration patterns during thin layer chromatography plates while the subscript numbers 1 and 2 indicate major and minor compounds, respectively (Dikeman and Green, 1992). Aflatoxin M1 and M2 are other significant members of the aflatoxin family and are metabolites of AFB1 and AFB2, respectively which are modified in the digestive tract of some animals and humans and can be isolated from milk and urine. Dominant aflatoxins produced by *A. flavus* are B1 and B2, whereas *A. parasiticus* produces two additional aflatoxins G1 and G2 (Payne, 1998). However, all the toxicological ability of the fungus varies considerably. Only about half of *A. flavus* strains produce AFs-producing species more than 10µg/kg (Turner *et al*., 2009)
Biosynthetically, the aflatoxins are all formed from the same precursor, versiconalhemiacetal acetate. AFB1 is the most prevalent aflatoxin usually found in cases of aflatoxicosis, and is responsible for acute toxicity, chronic toxicity, carcinogenicity, teratogenicity, genotoxicity and immunotoxicity (Lizarraga-Paulin *et al*., 2011).

**Conditions for Aflatoxin Contamination**

The production of mycotoxins within the fungus depends on food sources and the particular enzymes of the fungus and other environmental factors (Schmale, 1998). The growth of aflatoxicogenic fungi is directly related with the production of aflatoxin, so that conditions suitable for these fungal growth is favorable for aflatoxin production. The primary factors influencing fungal growth in stored food products are the moisture content (more precisely, the water activity) and the temperature of the commodity. Food grains are normally harvested at higher moisture content and then dried to bring down the moisture content up to safe level before storage. Thus, delay in drying to safe moisture levels increases risks of mould growth and mycotoxin production (Chulze, 2010).
Aflatoxin infection occurs in crops prior to harvest and once the grain reaches storage. It can be produced when maturing maize is under drought and insect stress with prolonged periods of hot weather. Post harvest contamination can occur if crop drying is delayed. It can also occur during storage of the crop if moisture is allowed to exceed critical values (Herrman, 2006). Payne (1992) also reported that a flatoxin contamination of maize before harvest has been associated with drought combined with high temperature as well as insect injury.
According to Schmale (1998) moulds produce aflatoxins under a wide range of conditions and, therefore, the potential for a challenge should always be considered with plant stress, harvest stress, storage stress and feed-out problems. Fungal spoilage of stored commodities and aflatoxin production highly depends on several important factors including moisture content, relative humidity in the

air and temperature of the environment (Lal, 1986). Under a production system with no irrigation, dryer soil conditions associated with higher temperature particularly after the peg development stage of groundnut favor infection by Aspergillus and the development of aflatoxin prior to harvest (Waliyar *et al*., 2005).

Some essential factors that affect aflatoxin contamination include the climate of the region, the genotype of the crop planted, the soil type, the minimum and maximum daily temperatures, and the daily net evaporation (Strosnider *et al*., 2006). Aflatoxin contamination is also promoted by stress or damage to the crop due to drought before harvest, the insect activity, a poor timing of harvest, the heavy rains during and after harvest, and an inadequate drying of the crop before storage (Lizarraga-Paulin *et al*., 2011).

Aflatoxin production in the grain can happen in the field in the storage conditions between 20 and $40^{o}$c with 10-20% of humidity and 70-90% relative humidity in the air (Carvajal and Castillo, 2007). *A. flavus* has relatively high moisture requirements among storage fungi (Amare *et al*., 2006). Hence, aflatoxin contamination of grains is aggravated by high seed moisture. Aflatoxin contamination is a perennial risk between 40°N and 40°S of the equator (PACA, 2013).

## Effects of Aflatoxin in Ethiopia

Aflatoxins are of major interest because of their impact on both human and animal health. The umbrella term aflatoxin refers to four different types of mycotoxins produced, which are $B_1$, $B_2$, $G_1$, and $G_2$. Aflatoxin $B_1$, the most toxic, is a potent carcinogen and has been directly correlated to adverse health effects, such as liver cancer, in many animal species. Generally, mycotoxins are nearly all cytotoxic, disrupting various cellular structures such as membranes, and interfering with vital cellular processes such as protein, RNA and DNA synthesis.

In Eastern Ethiopia, aflatoxin levels ranging from 5 to 250 ppb were detected in groundnut samples (Amare *et al*., 1995). Another study shows that 4.1µg/kg of aflatoxin was detected from maize in Ethiopia (Amare, 2010). Two major aflatoxin producing fungi namely, *A. flavus* and *A. nigur* are identified from groundnut at Northern Ethiopia by Dereje *et al*. (2012). Similarly Alemayehu *et al*. (2014) also reported that all the samples of sorghum and finger millet from Ethiopia were contaminated with Aspergillus species. In late 1985 *A. flavus* was isolated from 70% of the maize samples. Early in 1985 Dawit and Berhanu (1985), *A. flavus* was isolated from 70% of the maize samples and reported that 80% of the isolates were capable of producing aflatoxin.

A survey by Dereje *et al*. (2012) from Northern Ethiopia indicates that there is 100% positive for Aspergillus fungi from samples of groundnut. The presence of aflatoxins in food means a risk for both animals and human beings. Another survey by Amare (2010) from Ethiopia revealed that *Aspergillus* species has occurred from 94% of samples from all sample areas and aflatoxin was detected from 88% of the samples. Risk of aflatoxins exposure in Africa is very high (margin of exposure less than 10 in most countries). Aflatoxin has impact on agriculture (crop production and animal husbandry), health, trade, economy and food security. A survey by Lou (2008), at different locations of Ethiopia from maize indicates that around 50% of the samples were positive for AFB1 and 9.4% were positive for AFB2 at a range of 10.2-80µg/kg. Hence, this paper provides an overview on the impacts of aflatoxin on human and animal health and economy (trade) in Ethiopia.

## Effects on Human

The diseases caused by aflatoxin consumption are loosely called aflatoxicoses. Acute aflatoxicosis results in death; chronic aflatoxicosis results in cancer, immune suppression, and other "slow" pathological conditions (Herrman, 2006). In Ethiopia, aflatoxin B1 was detected in four major crops: barley, sorghum, teff and wheat (USAID, 2011). Similarly, Habtamu *et al*. (2001) has detected aflatoxin from maize, wheat, barley, teff, millet, sorghum, groundnut, faba bean, pea and pepper from Ethiopia, which are the major staple crops for the country. In this research AFB1 and AFG1 are detected, which are the more potent toxins. In this study 90% of the sample contain above 20µg/kg of aflatoxins from legume crops. Another study at Addis Ababa by Fufa and Urga (2007) revealed that 13.33% of samples of ground red pepper and 8.33% of Shiro were positive for aflatoxins (AFB1) at a range of 100 to 525 ppb. Aflatoxin analysis from Southwestern Ethiopia indicates that 3.33% of the samples tested showed positive result at concentrations of 92.59µg/kg (Chemed *et al*., 2016). In this experiment AFB1, AFG1, AFB2 and AFG2 were detected at a concentration of 41.08, 38.79, 7.56 and 5.16µg/kg, respectively. Abdi and Alemayehu (2014) also reported 36-100% aflatoxicogenic fungi incidence in Ethiopia from groundnut. Similarly, AFB1 contamination in maize in south Ethiopia was 22.72 µg/kg (Alemu *et al*., 2008).

Lewis *et al*. (2005) reported that in 2004 in Kenya, 125 people died and nearly 200 others were treated after eating aflatoxin contaminated maize which is the largest outbreak. The deaths were mainly associated with homegrown maize that had not been treated with fungicides or properly dried before storage. Due to food shortages at the time, farmers may have been harvesting maize earlier than normal to prevent thefts from their fields, so that the grain had not fully matured and was more susceptible to infection. An outbreak of aflatoxicosis also occurred in western India in 1974, resulting in 397 recognized cases and 106 deaths (Krishnamachari *et al*., 1975).

WHO (2004) reported that around 4.5 billion people are chronically exposed to aflatoxin contamination. The existing food shortage in Ethiopia forces people to consume what they might have otherwise rejected, even when the food is moldy and organoleptically unacceptable. This exposes at least some of the population to a higher risk of consumption of aflatoxin-contaminated food. Aflatoxin B1 is one of the most potent hepato-carcinogens known and hence levels of aflatoxins in the diet are an important consideration for human health. Aflatoxin B2 is of less toxicological significance since it is found at much lower levels than Aflatoxin B1, and is always present with Aflatoxin B1 (Burch and Rowsell, 2001). IARC (2002) has classified aflatoxin B1 as a group 1 carcinogen agent (that means carcinogenic to humans).

It has been estimated that aflatoxins may play a causative role in up to 30% of the cases of liver cancer globally each year (WHO, 2014). Carvajal and Castillo (2007) Aflatoxin link to DNA, RNA and proteins can affect all the living kingdom from virus to man, causing acute or chronic symptoms, they are mutagen, hepatocarcinogens and teratogens. And when aflatoxin is linked with DNA they form adducts that are biomarkers of risk of diseases.

AFB1 is the most prevalent aflatoxin usually found in cases of aflatoxicosis, and is responsible for acute toxicity, chronic toxicity, carcinogenicity, teratogenicity, genotoxicity and immunotoxicity (Lizárraga-Paulín *et al*., 2011). The survey by Dereje *et al*. (2012) revealed that, aflatoxin B1 is more prevalent in Ethiopia. In this survey an average of greater than 30ppb of AB1 was recorded. This is very much greater than the permissible level of aflatoxin which is 5ppb. This means these products are not safe for human consumption, international trade and for afro-processing. The high aflatoxin prevalence indicates the high exposure of human to this toxin and hence high health risk of the chemical. Level of carcinogenicity is in the order of AFB1>AFG1>AFB2>AFG2 (Dorner, 2004). The $LD_{50}$ of aflatoxin B1 is 0.36 mg/kg, the corresponding value for aflatoxin B2 is five times higher (Brase *et al*., 2013).

Aflatoxin contamination of major grains-maize, groundnut and sorghum occurs above safe level in many African countries (PACA, 2012). Exposure to aflatoxin can lead to several health-related conditions including acute and chronic aflatoxicosis, aflatoxin-related immune suppression, liver cancer, liver cirrhosis, as well as nutrition-related problems in children such as stunted growth (Wu *et al*., 2011). Children under 5 remain particularly vulnerable to aflatoxin exposure significantly hindering children's growth and development while damaging their immunity (PACA, 2014). Another report by USAID (2011) indicates aflatoxin has also been linked to kwashiorkor disease.

Williams *et al*. (2004) estimated that 4.5 billion of the world's population is exposed to aflatoxins. Aflatoxicosis shows various symptoms on affected organisms. Signs and symptoms include vomiting, abdominal pain and hemorrhaging, pulmonary edema, acute liver damage including fatty change, loss of digestive tract function, convulsions, cerebral edema, and coma. Other symptoms include yellow eyes, vomiting, abdominal swelling, water in the abdomen, leg swelling, general weakness, and drowsiness (APHOK, 2006). Children can also be affected through breast milk or orby direct consumption of weaning foods (PACA, 2013). Chronic symptoms of aflatoxin include decrease in growth rate, lowered milk or egg production, and immunosuppression (Mclean and Dutton, 1995).

A survey from Addis Ababa and its surrounding cities indicates that all milk samples were contaminated with AFM1 from lower (0.028µg/L) to higher (4.98µg/L) level. From this study 93% of the sample milk in the area exceeds the limit of 0.05mg/L set by the EU (Dawit *et al*., 2016). Similarly, only 8.2% of milk samples contained less than or equal to 0.05 mg/L of AFM1. The maximum level for aflatoxins set by the EU is 0,05 µg/L milk. The highest concentration of aflatoxins detected in this study was 4,98 µg/L. This indicates that there is high exposure of aflatoxin contamination in the area. The presence of AFM1 in milk poses a major risk for humans, especially children, as it can have immunosuppressive, mutagenic, teratogenic, and carcinogenic effects (Sefidgar *et al*., 2011). A report by PACA (2012) also indicates that aflatoxin contamination of key staple crops- maize, groundnut and sorghum occur above safe level which is higher than the EU and USA standard for many African countries.

A high contamination of food and feed products in Ethiopia may be due to, conducive climatic conditions, traditional crop production practices, inadequate harvesting, drying and storage practices, policy and institutional capacity, lack of awareness and high reliance on one or two crops for food. In addition, major staple grain crops in the country are contaminated with aflatoxin. PACA (2014) has reported Eastern and Southern Africa region are highly contaminated with aflatoxin occasionally above the internationally recommended maximum limits.

Aflatoxin can cause both acute and chronic aflatoxicosis. Aflatoxins, once ingested (because of their low molecular weight), are rapidly adsorbed in the gastro-intestinal tract through passive mechanism, and then quickly appear as metabolites in blood after just 15 minutes and in milk as soon as 12 hours post-feeding (Yiannikouris and Jouany, 2002; Moschini *et al*., 2006). Aflatoxin exposure contributes to between 4.6 and 28.2 percent of all liver cancer cases, most of which occur in Sub-Saharan Africa, Southeast Asia, and china, the regions with the highest aflatoxin exposure (USAID, 2011). Risk of liver cancer attributable to aflatoxins in Africa is extremely high (more than 1case per year per 100,000 people) (Kimanya, 2013).

Specific P450 enzymes in the liver metabolize aflatoxin into a reactive oxygen species (aflatoxin-8,9-epoxide), which may then bind to proteins and cause acute toxicity (aflatoxicosis) or to DNA and induce liver cancer (Wu and Khlangwiset, 2010).

According to Liu and Wu (2010), exposure to aflatoxin may also compound pre-existing health concerns. Individuals infected with the hepatitis B virus who have been exposed to aflatoxin have 30 times the risk of getting liver cancer than people who are hepatitis B-negative. About 40% of the hepatocellular carcinoma (liver cancer) in Africa can be attributed to aflatoxin (USAID, 2011). Agrios (2005) reported that most of the ingested aflatoxin is taken up by the liver, and animals given feed containing even less than the permissible amount of aflatoxin (20 ppb) almost invariably developed liver cancer.

## Effects on Animal

Aflatoxins also cause a variety of adverse effects in different domestic animals. In animals, aflatoxins impair growth and are immunosuppressive. Among livestock, they are particularly toxic to chickens. Effects on chickens include liver damage, impaired productivity and reproductive efficiency, decreased egg production in hens, inferior egg-shell quality, inferior carcass quality and, most important from a human perspective, increased susceptibility to disease (Herrman, 2006).

In livestock, consumption of very high levels of aflatoxins causes acute toxicity and death, while chronic consumption of lower levels can cause liver damage, gastrointestinal dysfunction, and decrease in appetite, reproductive function, growth, average daily gain, body weight and production (Khlangwiset , 2011). The effects of aflatoxicosis are similar in ruminants and non-ruminants. A dose of 0.2 mg/kg body weight can cause a decrease in weight gains. Aflatoxicosis has also been shown to cause decreased fertility, abortion, and lowered birth weights in sheep (Verma and Mehta, 1998).

A study by Dawit *et al*. (2016) from Addis Ababa and its surrounding cities revealed that an average of 97µg/kg of AFB1 was recorded from dairy feeds. In this study noug cake which is the major source of feed in the area has the highest concentration of AFB1 ranging from 290-397µg/kg. All the feeds exceeded 5µg/kg of AFB1, which is above the standard and unsafe for animal feed. Noug contributes a large share of edible production in Ethiopia, thus high concentration of AFB1 in noug indicates high risk of AFB1 on noug seed and oil. The high AFB1 concentration of feed indicates high risk of animals to be contaminated with the toxin, hence high risk of contamination of humans by AFM1 from meat, milk and milk products. The AFM1 distribution in some dairy foods made from contaminated milk is approximately: 40-60% in cheese, 10% in butterfat and <2% in buttermilk (Yusef and Marth, 1989). However, Lopez *et al*. (2001) found that the greatest proportion of AFM1 (60%) was in whey, while 40% AFM1 remained in cheese. Filazi and Sireli (2013) have reviewed different reports which indicate that aflatoxin is found on different food products from animals, including egg, fish, meat and chicken.

AFM1 concentrations in milk vary with the cow breed, the concentration of AFB1 in the diet, the amount and duration of consumption of contaminated food and the animal health (Lizárraga-Paulín *et al*., 2011). AFM1 is excreted within 12 h of consumption of contaminated feeds and is usually about 3% of the dietary intake of AFB1 (Applebaum *et al*., 1982; Battacone *et al*., 2003), but it varies from animal to animal, from day to day and from one milking to the other. Animals must ingest less than 50 and 25 µg of AFB1 per day or less than 10 to 20kg of feed contaminated with greater than 20µg/kg of feed to comply with the European regulatory levels of contamination and to maintain a safe level of AFM1 in milk (Pettersson, 1998). It is illegal to sell grain with levels greater than 20 ppb aflatoxin for lactating dairy cows, and the seller of the grain is responsible for damage resulting from the sale of grain (Jodie, 2012). Most of AFB1 and AFB2 ingested by mammal is eliminated through urine and faeces, however a fraction is biotransformed in the liver and excreted together with milk in the form of aflatoxins AFM1 and AFM2, respectively. Several studies shows that aflatoxin can occur on milk products including cheeses. Fallah*et al*. (2009) studied 210 cheese samples, and AFM1 at measurable level (50µg/kg) was detected in 76.6% of samples. Dashti *et al*. (2009) has also detected AFB1 from 80% of cheese samples, at a concentration of 23.8–452µg/kg.

The effects of aflatoxin contaminations are similar for all animals but the degree susceptibility varies with the species, age, sex and nutritional status of the animal, environmental factors, exposure level and duration of exposure. Young animals are particularly more susceptible to aflatoxin. Pregnant cows, calves, fattening pigs, mature cattle, and sheep fed low dosages of aflatoxin over long periods develop weakening, intestinal bleeding, debilitation, reduced growth, nausea, refusal of feed, predisposition to other infectious diseases, and may abort (Agrios, 2005). For most species the $LD_{50}$ (lethal dose) is between 0.5 and 10mg/kg body weight (Gong *et al*., 2002). No animal species is resistant to the acute toxic effects of aflatoxins. Males are more susceptible than females. There is considerable variation by species. A list of animals in order of decreasing sensitivity runs rabbits> ducks> turkeys> chicken> fish> swine> cattle> sheep (Grace, 2013).

## Economic Loss

In the USA, it was reported that income losses due to aflatoxin contamination cost an average of more than US$100 million per year to US producers (Coulibaly *et al*., 2008). According to Cardwell *et al*., 2008, aflatoxin contamination of agricultural crops, such as groundnut and cereals, causes annual losses of more than $750 million in Africa. In addition to quantitative loss aflatoxin also causes quality loss of commodity. According to WHO (2011), aflatoxin contamination leads to 64% reduction in food quality in Africa.

Aflatoxin contaminations of major crops also influence food security by directly reducing the availability of foods. Producers of the affected crops may also earn less due to product rejection, reduced market value, lower yield and morbidity and mortality of animals (PACA, 2012). In Ethiopia these crops are very important in day to day dietary consumption of the peoples. Hence there is high risk of aflatoxin contamination in the country.

According to PACA (2012), the economic impact of aflatoxin contamination depends on the contribution that the susceptible commodity makes to the country's consumption and income, especially on the country share in the country share for the households, share of income and awareness about the problem. Food in-secure households are more likely to consume contaminated food. Aflatoxin affects food security by affecting access to food, use and safety of food, availability of food. A report by PACA (2014) indicates that Africa loses US$450 million per year from lost during export trade due to aflatoxins.

The chronic and acute exposures of cattle to aflatoxin cause significant economic loss. In addition to financial losses and economic damage to agricultural and animal husbandry, losses due to aflatoxin contamination of foods include major pharmaceutical and health costs to treat food poisoning. Consumption of aflatoxin contaminated feed reduces productivity of livestock (Dawit *et al*., 2016) which is another economic loss. Different countries have regulations on aflatoxin contaminated products which have direct impact on regional and international trade. If all countries were to adopt EU standards on aflatoxins, then global trade would decline by $3 billion (Dohlman, 2008). In addition there is a cost of management for aflatoxin and its prevention.

**Regulation of Aflatoxin**

When it became evident that aflatoxin exposure caused cancer in many species, most countries, established various regulations for aflatoxin levels (either total aflatoxins or for AFB1) in food and/or feed in order to limit exposure to this group of mycotoxins (Van-Egmond *et al*., 2007). Many countries have set a limit for a maximum tolerable level of aflatoxin in food and food stuffs and restrict the import of contaminated products to their country. Aflatoxin is becoming a major impediment to the global exchange/trade of plant and plant products. Aflatoxin regulation creates a demand for aflatoxin safe food. Different countries have different regulations for aflatoxin to protect consumers from the harmful effects of mycotoxins that may contaminate foodstuffs, as well as to ensure fair practices in food trade. The determination of aflatoxins has been carried out using TLC, HPLC, LC–MS, LC–MS–MS, ELISA and immunological methods.

The hazardous nature of aflatoxin to humans and animals has forced the need for establishment of control measures and tolerance levels by national and international authorities. The number of countries regulating aflatoxins has significantly increased over the years. Such lower limits for aflatoxin had an enormous impact on the ability of developing countries in Africa like Ethiopia to export goods. Aflatoxin is more problem for developing nations than developed countries. In the developing countries, where food supplies are already limited, legal measures may lead to lack of food and to excessive prices.

Grains for animal feed in the United States are allowed 300 ppb aflatoxin. According to Hell and Mutegi (2010), aflatoxin research in Africa is necessary to get policymakers in the Sub-Saharan region to recognize that the increased implementation of pre- and post-harvest interventions is important for increasing food security and ensuring food safety to protect the short and long term health of the population.

For example, a research by Dejene *et al*. (2012) from Northern Ethiopia on groundnut revealed that, from the total samples analyzed, 83.9% were unsafe for direct human consumption as per the EU MTIL and 46.6% were unfit for export to EU counties (as per the EU safe limit for import of groundnut); and on the basis of the FAO MTL, 16.6% of the samples exceeded the 30 ppb limit. The average concentration for the total samples had 10 times greater than the recommended maximum aflatoxin level. Similarly, Habtamu *et al*. (2001) also reported that, in many parts of Africa human food staples exist which contain 10 to 30 times the recommended maximum.

The maximum level of 8mg/kg of AFB1 has been established in food subjected to sorting or physical treatment before human consumption, and the corresponding 2 mg/kg of AFB1 for direct human consumption. The maximum level of 0.05mg/L has been set for AFM1 in milk. The Food and Drug Administration in the USA (USFDA) sets action level for AFM1 in milk and total aflatoxin in animal feed to be 0.5mg/L and 20mg/kg respectively (National Grain and Feed Association, 2011). Ethiopia has no aflatoxin and other mycotoxin regulation (Habtamu *et al*., 2001; Dejene *et al*., 2012, PACA, 2014). This increases the exposure of humans and animals from aflatoxin contamination. However, aflatoxin regulation is not the mandatory case in Ethiopia, because almost all the effect is from indigenous contamination of commodities. Hence, more emphasis should be given for control of the toxin.

Aflatoxin remains largely unregulated throughout Africa. As of 2003, aflatoxin regulations existed for five countries in Africa. However, 99% of Europe's populations are protected from aflatoxin contamination. The accepted limits of AFB1 and total aflatoxins in foods are 5 and 10 µg/kg, respectively, in more than 75 countries around the world whilst they are 2 and 4 µg/kg in the European Union (Van Egmond and Jonker, 2004).

Aflatoxin regulation has great effect on international trades, especially for the developing countries like Ethiopia. For example, FAO (2002) reported that developing countries account for approximately 95% of world groundnut production, but are unable to sell large quantities of groundnut on the international market because of aflatoxin contamination. Hence, high contamination of commodities in Ethiopia largely affects export, in which the country largely depends.

**Management of Aflatoxin**

The complex nature of aflatoxin contamination means that a holistic and multidisciplinary approach is required to mitigate the risk of human and animal exposure to this toxin. There is a need to increase awareness of aflatoxins and support risk mitigation practices. Most people did not know the effect of aflatoxin contaminations (Dawit *et al*., 2016). PACA (2014) also reported that Ethiopia has limited laboratories and trained personnel and standard authorities.

There are three primary interventions to mitigate the effects of aflatoxicosis on human liver disease: clinical, dietary, and agricultural (USAID, 2011). Aflatoxin is a complex problem that can be addressed through integrated measures and coordinated actions. Aflatoxin can be prevented at pre-harvest and post harvest by controlling aflatoxicogenic fungi and aflatoxin contamination. Aflatoxin contamination can occur at any time. Aflatoxins can be controlled before contamination in the field and after contamination after harvest.

**Pre-harvest Aflatoxin Prevention**

Pre-harvest measures that are efficient in reducing aflatoxin levels are the same as those that will enhance yields. Cultural practices that tend to expose plants to greater drought stress will lead to higher levels of aflatoxin. Cultural practices including field selection, hybrid selection, fertilization, planting date and density, irrigation, weed management, crop rotation, tillage, insect and disease management, and harvest practices on aflatoxin concentrations. Use of farming techniques, such as crop rotation and interventions to reduce exposure to environmental stress, can also reduce aflatoxin contamination. Environmental stressors greatly impact the health and virility of crops. Drought stress is a major contributor to pre-harvest aflatoxin contamination (USAID, 2011). Cultivating varieties for major aflatoxin prone commodities which are resistant to fungal growth and/or aflatoxin contamination is essential. Measures to stop the infection process by controlling the aflatoxin causing fungi in the field also are achieved through use of pesticides. Therefore, effective management of aflatoxicogenic fungi in the field and avoiding stress for the crop will prevent aflatoxic contamination grains and hence reduce risks of human and animal exposure and also economic losses.

**Post -harvest Control**

Postharvest contamination of grain by aflatoxin could be take place during processing, storage, transportation as well as marketing. Aflatoxin contamination is difficult to eliminate totally from commodities, but it is possible to reduce aflatoxin contamination and by prevention of occurrence of aflatoxin. Aflatoxins can be detoxified or removed from contaminated food and nutrients by physical, chemical or biological methods. The inactivation of these compounds by physical and chemical methods have not proved to be effective and economically viable (Mishra and Das, 2003).

Ammoniation is also used as an effective and practical application for decontamination of agricultural products containing aflatoxins (Allameh *et al*., 2005). An experiment by Nyandieka *et al*. (2009) indicates that ammoniation procedures destroyed 90% of aflatoxin from contaminated maize. Appropriate storage of grains and animal feeds is essential to reduce aflatoxin contamination of the products. Moisture and temperature influence the growth of toxigenic fungi in stored commodities. Harvested commodities should be dried as quickly as possible to safe moisture levels of 10 – 13% for cereals. Aflatoxin contamination can increase 10 fold in a 3-day period, when field harvested maize is stored with high moisture content (Hell *et al*., 2008).

Reduction and detoxification of aflatoxin is often achieved physically (sorting, physical segregation, flotation etc.), chemically (e.g. calcium hydroxide, ammonia) and microbiologically. Decontamination processes inactivate, destroy or remove the toxin from food. Aflatoxins are susceptible to some microorganisms such as fungi, bacteria and yeasts, being for this reason studied as a form of biological degradation (Caldas *et al*., 2011). Use of different microorganisms such as *Lactobacillus pentosus* and *Lactobacillus brevis*is reported for reducing aflatoxin in livestock feed (Haskard *et al*., 2001).Similarly, use of atoxigenic strains of *Aspergillusflavus* (aflasafe) is also important biocontrol methods. Results from Nigeria show that reduction of 80-90% aflatoxin contamination in maize and groundnuts (AATF, 2000).

Some reports certain processing methods may significantly decrease aflatoxin levels in the end product. For example one study by Siwela *et al*. (2011) show that roasting of groundnut had a dramatic effect on the levels of aflatoxin found in the nuts. However, another report by Tripathi and Mishra (2010) revealed that aflatoxins are thermostable, so the physical treatment by heat results in only small changes in their levels. One of the most used treatments for milk processing is heating; however, AFM1 is resistant to any thermal treatment (Carvajal *et al*., 2003; Park, 2002).

Generally, all the report indicates that Ethiopia is highly affected by aflatoxin contamination of grains (especially, maize and groundnut) and animal commodities. There are also a lot of challenges for aflatoxin effect including, reliance on one or two crops for food (especially maize and groundnut), high occurrence of aflatoxins in the foods, conducive climatic conditions, low level of awareness on the problem of aflatoxins contamination, low capacity for risk assessment and management for aflatoxins, traditional crop production practices, inadequate harvesting, drying and storage practices, among others.

## CONCLUSION

Aflatoxin is a type of mycotoxin produced by Aspergillus mold. Aflatoxin is the most well known and researched mycotoxin. Ethiopia is most favorable for aflatoxicogenic fungi and aflatoxin contamination, especially AFB1. Reports show that maize and groundnut are the most contaminated commodities in the country. These two commodities are most important in day to day dietary sources of the people in most regions of Ethiopia. The level of contamination for most commodities in the country is also very much greater than the international standard. Similarly milk and milk products are also contaminated with AFM1 above the standard level.

There are basically six groups of aflatoxins, AFB1, AFB2, AFG1, AFG2, AFM1 and AFM2; from which AFB1 are the most potent aflatoxins to cause health damage to human and animal. AFB1 is the most the most common contaminant of most Ethiopian commodities. Aflatoxins are toxic to human and animal and cause different diseases. There are two main ways people are usually exposed to aflatoxin. The first is when someone takes in a high amount of aflatoxins in a very short time. This can cause, liver damage, liver cancer, mental impairment, abdominal pain, vomiting, death and others. The other way people suffer aflatoxin poisoning is by taking in small amounts of aflatoxins at a time, but over a long period. This might happen if a person diet has a small amount aflatoxin. This can cause growth and development impairment, liver cancer, DNA and RNA mutation and others.

The effect of aflatoxin on human depends on age, gender, level of exposure, duration of exposure, health condition, strength of their immune system, diet and environmental factors. In addition to health effect, aflatoxin cause huge economic loss to Ethiopia and many developing countries. Commodities can be contaminated with aflatoxicogenic fungi and aflatoxin at any time, before harvest and after harvest. The prevention of aflatoxin once occurs and treatment of aflatoxicosis is difficult. However, there are some mitigation mechanisms pre- and post harvest, especially proper storage is essential with proper moisture and temperature. Moreover, awareness creation on aflatoxin contamination, its effect and management is essential.

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