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Occurrence, importance and control of mycotoxins: A review

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Abstract: Mycotoxins are poisonous chemical compounds produced by certain fungi. There are five mycotoxins or groups of mycotoxins that occur quite often in food: deoxynivalenol/Nivalenol, zearalenone, ochratoxin, fumonisins and aflatoxins. The fungi that produce mycotoxins in food fall broadly into two groups: those that invade before harvest, commonly called field fungi, and those that occur only after harvest, called storage fungi. There are three types of toxicogenic field fungi: plant pathogens such as *Fusarium graminearum* (deoxynivalenol, nivalenol); fungi that grow on senescent or stressed plants, such as *Fusarium moniliforme* (fumonisin) and sometimes *Aspergillus flavus* (aflatoxin); and fungi that initially colonize the plant before harvest and predispose the commodity to mycotoxin contamination after harvest, such as *Penicillium verrucosum* (ochratoxin) and *A. flavus* (aflatoxin). The favourable conditions for mycotoxins production are instigated with poor hygienic conditions at the time of transportation and storage, high temperature and moisture content and heavy rains. Mycotoxins are distributed in different items such as animal feeds, cereal crops, leguminous plants and animal products. Concentrated animal feed stuffs harbour highest level of mycotoxins. Noug cake and sorghum was warranted as the main source of aflatoxin contaminant among those concentrated animal feeds. Health effects occur in companion animals, livestock, poultry and humans because aflatoxins are potent hepatotoxins, immunosuppressant, and mutagens and carcinogens. Factors that affect mycotoxins production and

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Marta Tola graduated from Addis Ababa University in chemistry and Dr Bedaso Kebede graduated from Addis Ababa University since July, 2010. Their research interests are focused on the animal diseases and public health. The review in this paper relates to the impact of mycotoxins on animals and human, occurrence of, analytical methods and regulations of mycotoxins.

PUBLIC INTEREST STATEMENT

Mycotoxins are poisonous chemical compounds produced by certain fungi. The fungi: those fungi that produce mycotoxins in food fall broadly into two groups that invade before harvest, commonly called field fungi, and those that occur only after harvest, called storage fungi. The favourable conditions for mycotoxins production are instigated with poor hygienic conditions at the time of transportation and storage, high temperature and moisture content and heavy rains. Mycotoxins are distributed in different items such as animal feeds, cereal crops, leguminous plants and animal products. Noug cake and sorghum was warranted as the main source of aflatoxin contaminant among those concentrated animal feeds. Health effects occur in companion animals, livestock, poultry and humans because aflatoxins are potent hepatotoxins, immunosuppressant, and mutagens and carcinogens. Therefore, public should aware about impact of mycotoxins on the human and animals.

contamination can be categorized as physical, chemical and biological. Therefore, African countries particularly Ethiopian governmental jurisdictions shouldimplement and regulate level of mycotoxins in animal feed stuffs and human foods.

Subjects: Bioscience; Environment & Agriculture; Environmental Studies & Management; Food Science & Technology

Keywords: mycotoxins; occurrence; importance and control

1. Introduction

Mycotoxins are poisonous chemical compounds and secondary metabolites produced by fungus or moulds. Those mycotoxins that do occur in food and/or feedstuffs have great significance in the health of humans and livestock. Since they are produced by fungi, mycotoxins are associated with diseased or mouldy crops, although the visible mould contamination can be superficial. The effects of some food-borne mycotoxins are acute, symptoms of severe illness appearing very quickly. Other mycotoxins occurring in food have longer term chronic or cumulative effects on health, including the induction of cancers and immune deficiency. There are five mycotoxins or groups of mycotoxins that occur in food: deoxynivalenol/Nivalenol, zearalenone, ochratoxin, fumonisins and aflatoxins. The fungi that produce mycotoxins in food fall broadly into two groups: those that invade before harvest, commonly called field fungi, and those that occur only after harvest, called storage fungi. There are three types of toxicogenic field fungi: plant pathogens such as *Fusarium graminearum* (deoxynivalenol, nivalenol); fungi that grow on senescent or stressed plants, such as *Fusarium moniliforme* (fumonisin) and sometimes *Aspergillus flavus* (aflatoxin); and fungi that initially colonize the plant before harvest and predispose the commodity to mycotoxin contamination after harvest, such as *Penicillium verrucosum* (ochratoxin) and *A. flavus (*aflatoxin) (Ayalew, 2010). The favourable conditions for mycotoxins production are instigate with poor hygienic conditions at the time of transportation and storage, high temperature and moisture content and heavy rains (Food Nutrition and Agriculture (FAO), 1991, see Table 1).

Mycotoxins are ubiquitous and accessible in different materials. It occurs in animal feeds, human foods, animal products and soil. Animal feeds commonly harbour mycotoxins are wheat bran, noug-cake, pea hulls and maize grain. An animal product like milk is the source of mycotoxins for human being (Gizachew, Szonyi, Tegegne, Hanson, & Grace, 2016). Aflatoxigenic fungi have worldwide distribution. In temperate and tropical areas these species of *Aspergillus* have ubiquitous distribution and are found in soil used for growing crops (Gourami & Bullerman, 1995). These fungi also have distribution in storage areas, processing facilities and in the distribution systems for manufactured products. The production of aflatoxins is associated with spore production by species of *Aspergillus* (Calvo, Wilson, Bok, & Keller, 2002). Strains of *A. flavus* can vary in aflatoxin capability from non-toxic to highly toxigenic and are more likely to produce more aflatoxin (Aflatoxin B1 (AFB1)) than AFG1. Strains of *Aspergillus parasiticus* generally have less variation in toxigenicity and generally produce AFB1 and varying amounts of AFB2, AFG1 and AFG2. Fusarium moulds or fungi are the most economically important source of trichothecene mycotoxins. Trichothecenes are produced by several genera of fungi, including Fusarium, Stachybotrys, Myrothecium, Trichothecium, Trichoderma, Cephalosporium, Cylindrocarpon, Verticimonosporium, and Phomopsis (Scott, 1989). The genus includes many field fungi capable of infecting wheat, corn, barley, oats, and forages. Fusarium is most common in temperate climates, but contamination of grains is reported worldwide. Trichothecenes are potent inhibitors of protein synthesis and are toxic to moulds, bacteria, plants, and animals (Council for Agriculture, Science & Technology, 2003; Joint FAO/WHO Expert Committee on Food Additives, 2001; Placinta, D'Mello, & Macdonald, 1999). *Fusarium* is a major agricultural plant pathogen of temperate growing regions, where it causes *Fusarium* head blight in wheat, barley, triticale, and other grains. *F. graminearum* has an optimum temperature range for growth of 26–28°C at a water activity (*a*W) greater than 0.88. *Fusarium culmorum* grows optimally at 21°C when *a*W_0.87. While increased rainfall will increase *Fusarium* head blight, the incidence of blight is primarily affected by moisture at anthesis when the temperature is in the optimum range (Miller, 2002). Moisture

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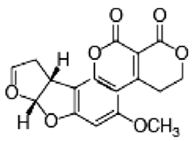
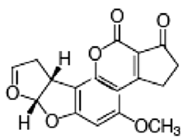
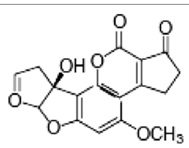
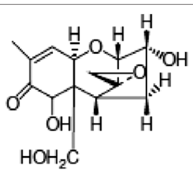
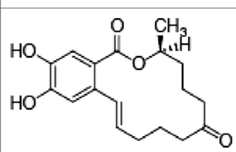
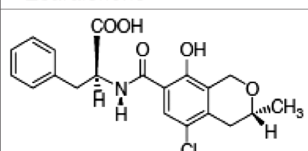
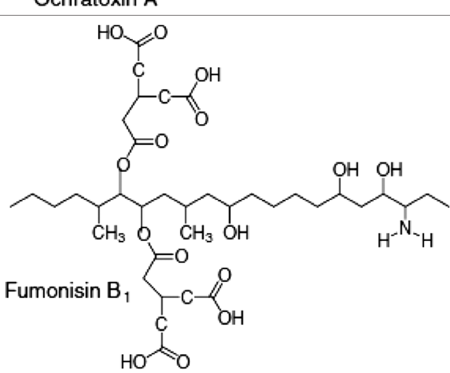
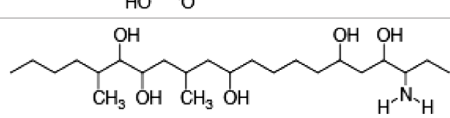
Table 1. Summary on mycotoxins chemical structures, names, analytical methods and maximum limit permitted

No	Mycotoxins chemical structures and names	Analytical methods	Maximum limit permitted
1	 Aflatoxin G_1	LC-MS, HPLC-FL (Zöllner & Mayer-Helm, 2006)	10 μg/kg (FAO, 1997)
2	 Aflatoxin B_1		
3	 Aflatoxin M_1		
4	 Deoxynivalenol	TLC (Ostry & Skarkova, 2000); HPLC (Walker & Meier, 1998)	750 μg/kg (FAO, 1997)
5	 Zearalenone	HPLC-FL (Krska, Welzig, & Boudra, 2007; Mateo, Mateo, Hinojo, Llorens, & Jiménez, 2002; Urraca, Benito-Peña, Pérez-Conde, Moreno-Bondi, & Pestka, 2005; Urraca, Marazuela, & Moreno-Bondi, 2004; Visconti & Pascale, 1998), LC-MS (Berthiller et al., 2006)	1000 μg/kg (FAO, 1997)
6	 Ochratoxin A	LC-FL (Becker, Degelmann, Herderich, Schreier, & Humpf, 1998; Wilkes & Sutherland, 1998), LC-MS and HPLC-FL (Zöllner & Mayer-Helm, 2006)	5 μg/kg (FAO, 1997)
7	 Fumonisin B_1	HPLC-FL (Wilkes & Sutherland, 1998), LC-MS (Zöllner & Mayer-Helm, 2006)	1000 μg/kg (FAO, 1997)
8	 Hydrolyzed Fumonisin B_1		

at silk emergence and wet weather later in the season increase Gibberella or pink ear rot caused by *F. graminearum* in corn. OTA occurs naturally with a greater frequency in a variety of cereal grains (barley, wheat, oats, corn, and beans), peanuts, dried fruits, grapes/raisins, cheese, and other food products. OTA accumulates in the food chain because of its long half life. Citrinin usually co-occurs with OTA, and commonly contaminates cereal grains, including wheat, barley, oats, corn, and rice. Citrinin also contaminates peanuts and fruits. Tremorgen-producing fungi grow on a wide variety of foodstuffs, including dairy or grain-containing products intended for human consumption (e.g. cheeses and pastas), stored grains and nuts (e.g. peanuts and walnuts) and a number of forages (e.g. legumes and grasses) consumed by livestock species, and even garbage and compost piles can be sources of tremorgenic mycotoxins (Boysen et al., 2002; Burrows & Tyrl, 2001; Young, Villar, Carson, Imerman, & Moore, 2003).

Mycotoxins are endangering human health, animal production and countries economy (World Health Organization, 2006). Significantly visible health problems are cancer, immunosuppression and impaired growth (Bondy & Pestka, 2000; Gong et al., 2004; Khlangwiset, Shephard, & Wu, 2011). Aflatoxins, on a worldwide scale, are important mycotoxins in human foods and animal feedstuffs (Williams et al., 2004). Aflatoxin contamination causes economic losses of corn, cottonseed, peanuts, sorghum, wheat, rice and other commodities, and economic losses of processed food and feedstuffs. Commodities considered unsafe for human consumption can be incorporated into animal feedstuffs (Coppock & Swanson, 1986). Systemic aspergillosis by aflatoxigenic fungi was considered to contribute to immunosuppression (Mori et al., 1998). Aflatoxins are teratogenic (Robens & Richard, 1992). Aflatoxicosis in the human population, especially in areas stricken by poverty and drought and other adverse growing conditions is an important public health problem (Williams et al., 2004). Fungi belonging to the genera Penicillium, Aspergillus, Claviceps, and Neotyphodium can produce tremorgenic mycotoxins, which are secondary fungal metabolites that elicit either intermittent or sustained tremors in vertebrate species (Burrows & Tyrl, 2001; Cole & Cox, 1981; Selala, Daelemans, & Schepens, 1989). Slaframine is an alkaloidal mycotoxin produced by the fungus *Rhizoctonia leguminicola* that causes profuse salivation (slobbers) in animals. *R. leguminicola* is a common fungal pathogen of red clover (*Trifolium pratense*) and causes a syndrome known as black patch disease in the plant (Gupta, 2007).

The most commonly recognized aflatoxigenic fungi are *A. flavus*, *A. parasiticus* and *A. nomius*. Other fungi reported to produce aflatoxins are *Aspergillus bombycis*, *Aspergillus ochraceus* and *Aspergillus pseudotamari* (Bennett & Klich, 2003; Klich, Mullaney, Daly, & Cary, 2000; Mishra & Das, 2003). *A. flavus* and *Aspergillus fumigatus* have also been identified as pathogenic to animals and humans (Barton, Daft, Read, Kinde, & Bickford, 1992; Drakos et al., 1993; Pepeljnjak, Slobodnjak, Šegvić, Peraica, & Pavlović, 2004). Aflatoxins can be produced in tissues by toxigenic fungi. Assays of cultured *A. flavus* and *A. fumigatus* isolated from tissues have shown these fungi can produce aflatoxins, and chemical analyses of infected tissues have shown aflatoxins to be present (Matsumura & Mori, 1998; Mori et al., 1998; Pepeljnjak et al., 2004). Aflatoxins being produced in tissues have not been shown to cause liver lesions typical of aflatoxicosis.

Zearalenone is a nonsteroidal estrogenic mycotoxin produced by several species of Fusarium fungi. The primary producer of zearalenone is *F. graminearum* (teleomorph *Gibberella zeae*). Additional Fusarium fungi capable of producing zearalenone include *F. culmorum*, *Fusarium verticillioides* (*moniliforme*), *sporotrichioides*, *semitectum*, *equiseti*, and *oxysporum*. Contamination of cereal grains by zearalenone has been reported worldwide, primarily in temperate climates. Typically, zearalenone concentrations are low in grain contaminated in the field, but increase under storage conditions with moisture greater than 30–40% (Gupta, 2007). Zearalenone is commonly detected in grains with another Fusarium mycotoxin deoxynivalenol. Zearalenone is heat stable, but can be partially destroyed during extrusion cooking of cereals (Castells, Marín, Sanchis, & Ramos, 2005).

Fumonisins B1 and B2 are a group of naturally occurring mycotoxins produced by the fungus, *F. verticillioides* (formerly *F. moniliforme*). Ochratoxins and citrinin are produced by several species of genera Aspergillus and Penicillium. The two most common species that produce ochratoxin A (OTA) are *Aspergillus ochraceus* and *P. verrucosum*. These fungi are ubiquitous and the potential for contamination of animal feed and human food is widespread. Aspergillus spp. appears to produce ochratoxins at conditions of high humidity and temperature, whereas some Penicillium spp. may produce ochratoxins at temperatures as low as 5°C. OTA has been found in a variety of food/feed, with levels in commodities used as feed ranging up to 27 ppm, and with levels in foodstuffs for human consumption in the range of trace to about 100 ppb (Gupta, 2007). The levels of OTA and citrinin have been found far lower in human food than in raw animal feed, because during processing and baking of human food citrinin is almost eliminated and OTA is significantly reduced.

Most governmental jurisdictions regulate the levels of mycotoxins allowed in animal feedstuffs and human foods because of their toxicity. Worldwide, mycotoxins because of their prevalence and toxicity are important in public health. Public health concerns centre on both primary poisoning from aflatoxins in commodities, food and feedstuffs, and relay poisoning from aflatoxins in milk. The allowable levels of aflatoxins in animal feedstuff and human foods vary with governmental jurisdictions. However, in Ethiopia there are little studies on mycotoxins and paucity of information on the importance, occurrence and control of the mycotoxins. Therefore, the objective of this review is to overview occurrence, importance and control of mycotoxins.

2. Occurrence and distribution of mycotoxins

Mycotoxins are available in different items such as animal feeds, cereal crops, leguminous plants and animal products. All cereal crops can contain aflatoxins. Intensive cropping practices and decreased genetic diversity in cereal crops probably contribute to increased preharvest infections of commodities with fungi that produce aflatoxins (Brown, Chen, Cleveland, & Russin, 1999; Lillehoj, 1992). Preharvest contamination of crops with aflatoxins occurs in the temperate and tropical regions. The seeds in growth-stressed plants are the most susceptible to fungal invasion and aflatoxin production. The most common recognized plant stressors are drought, insect damage and timing of irrigation. Postharvest contamination occurs worldwide when conditions in the storage unit exist for the growth of Aflatoxigenic fungi. Aflatoxigenic fungi can grow in feedlot manure (Hendrickson & Grant, 1971). Insects spread the spores of aflatoxigenic fungi to plants and the fungi colonize areas of insect damage. The flower and silk in corn can be portals of entry for species of *Aspergillus* (Diener et al., 1987). Cottonseed can be a source of aflatoxins in animal diets. Preharvest contamination of cottonseed occurs (Jaime-Garcia & Cotty, 2003). Insect damage, timing of irrigation or rain, relative humidity around the bolls, stage of maturity and variety of cotton can be factors in causing preharvest contamination of cottonseed with aflatoxins (Lillehoj, Wall, & Bowers, 1987; Russell, Watson, & Ryan, 1976). In stored cottonseed growth of aflatoxigenic fungi may occur when the average moisture level in stored cottonseed is greater than 7–8%. The lipids and proteins in cottonseed enhance aflatoxin production (Mellon & Cotty, 1998; Mellon, Cotty, & Dowd, 2000). Peanut hay, peanuts and peanut by-products are an important source of mycotoxins (Cullen & Newberne, 1994; McKenzie, Blaney, Connole, & Fitzpatrick, 1981). Aflatoxins generally are the most concentrated in the seeds. The growth of aflatoxigenic fungi can occur in stored peanuts when moisture exceeds 8% and ambient temperature is above 25°C. Drought-stressed peanuts have decreased native resistance to infection by aflatoxin producing fungi (Wotton & Strange, 1987). Phytoalexin produced by the infected peanut seed increased and inhibited the growth of *A. flavus*, but aflatoxin levels continue to increase for an additional day. Drought-stressed peanut seeds have decreased production of phytoalexin and aflatoxin production in drought-stressed peanut kernels is limited by available moisture. Distillers' by-products can be a source of aflatoxin (Hesseltine, 1984). Corn and other high starch commodities contaminated with aflatoxins can be salvaged by using them for alcohol production. Aflatoxins are not destroyed by the fermentation process. On a dry matter basis, the concentration of aflatoxins in the stillage, compared to aflatoxins in the feedstock, is increased due to the loss of starch. Approximately 40% of the aflatoxins are in the syrup (distillers' solubles) fraction and 60% are in the solids fraction. Zearalenone can be produced on numerous substrates, including wheat, barley, corn, corn silage, rice, sorghum, and occasionally in forages. Commercial corn-based human feedstuffs from retail outlets in several countries frequently contain fumonisins (Pittet, Parisod, & Schellenberg, 1992; Stack & Eppley, 1992; Sydenham, Shephard, Thiel, Marasas, & Stockenstrom, 1991).

Concentrated animal feedstuffs harbour highest level of mycotoxins. For instance, the lowest level of aflatoxin B1 contamination recorded from silage feed, which is roughages, was 7 μg/kg. However, the highest level of aflatoxin B1 contamination traced about 419 μg/kg in concentrate animal feeds like wheat bran, noug cake and sweat pea hull. Noug cake was warranted as the main source of aflatoxin contaminant among those concentrated animal feeds. Because, Noug is indigenous and contributes up to 50% oil-seed crop with its oil content varying from 30 to 50%. The oil factories produce cooking oil by pressing the noug seed and extracting the oil while the remaining noug cake is sold as animal feed to the feed processors or directly to the farmers. Noug cake is increasingly used in Ethiopia for its high nutrient content to increase animal productivity in small scale or intensifying system. It is also exported to North America and Europe, where it is mainly used for bird–feed (Gizachew et al., 2016).

Mycotoxins contamination intensity in leguminous crop varies geographically and groundnut is main source of mycotoxins. According to study on natural occurrence of Toxigenic fungi species and aflatoxins in four different location like Tankua abergele (53.3 ppb), Rama research centre (33.9 ppb) and the rest two Merebleke and Tahtay adiabo were less than 20 ppb toxin contaminant and it indicates that rate of contamination fluctuated based on location (Assefa, Teare, & Skinnes, 2012). Groundnut seed is predominantly infected with *A. flavus* and *Aspergillus niger* (Gebreselassie, Dereje, & Solomon, 2014).

Cereal crops like barley, sorghum, teff and wheat are the main source of mycotoxins. Deoxynivalenol occurred in barley, wheat and sorghum with an overall incidence 48.8% of 84 suspected samples. Despite Fumonisins and Zearalenone occurred only in sorghum sample. Hence, Aflatoxin and Ochratoxin detected from wheat, sorghum, teff and barley. Among these cereal crops sorghum is the major source of mycotoxin contaminant because of wide spread storage of sorghum grain underground rise (pits) leading to elevated seed moisture contents. Aflatoxin B1 was detected in 8.8% of the 352 samples analysed at concentrations ranging from trace to 26 μg/kg. Ochratoxin occurred in 24.3% of 321 samples at a mean concentration of 54.1 μg/kg and a maximum of 2106 μg/kg. Deoxynivalenol occurred in barley, sorghum and wheat at 40 - 2340 μg/kg. Nivalenol was detected at 40 μg/kg in a wheat sample and at 50, 380 and 490 μg/kg in three sorghum samples. Fumonisins and Zearalenone occurred only in sorghum samples with low frequencies at concentrations reaching 2.17 and 32 μg/kg, respectively (Ayalew, Ferhmann, Lepschy, Beck, & Abate, 2006).

An animal product like milk is the main source of aflatoxin contamination for human being. A total of 110 raw milk samples collected only nine (8.2%) of the samples contained less than or equal to 0.05 μg/l of Aflatoxin M1. However, 29(26.3%) milk samples exceeded 0.5 μg/l (Gizachew et al., 2016).

3. Importance of mycotoxins

Mycotoxicoses in human like other toxicological syndromes can be categorized as acute or chronic. Acute toxicity has a rapid onset and an obvious toxic response, while chronic toxicity is characterized by low dose exposure over a long time period leading to cancer and other generally reversible effects (James, 2005). Aflatoxin contributes factor for the disease like Kwashiorkor and Reye's syndrome when children suffering it (Blunden, Roch, Rogers, Coker, & Bradburn, 1991); immunosuppression in children (Turner, Moore, Hall, Prentice, & Wild, 2003). Despite this, ruminants are less affected than non ruminant animals. However, production (milk, beef or wool), reproduction and growth can be altered when ruminants consume mycotoxin contaminated feed for extended periods of time (Hussein & Brasel, 2001).

Health effects occur in companion animals, livestock, poultry and humans because aflatoxins are potent hepatotoxins, immunosuppressant, and mutagens and carcinogens (Eaton & Gallagher, 1994). Zearalenone has major effects on reproduction that can lead to hyperestrogenism. Prepubertal swine are the most sensitive species. Typical clinical signs of hyperestrogenism are swelling of the vulva, increase in uterine size and secretions, mammary gland hyperplasia and secretion, prolonged oestrus, anestrus, increased incidence of pseudopregnancy, infertility, decreased libido, and secondary complications of rectal and vaginal prolapses, stillbirths and small litters (Gupta, 2007). Fumonisins (B1 and B2) toxic metabolites that are usually found in corn have been implicated in field cases of porcine pulmonary oedema (PPE) (Colvin, Cooley, & Beaver, 1993; Harrison, Colvin, Greene, Newman, & Cole, 1990; Osweiler et al., 1992) and equine leukoencephalomalacia (ELEM) (Wilson et al., 1990). Experimentally, fumonisin has been shown to cause liver damage in multiple species including pigs, horses, cattle, rabbits, and primates (Gumprecht et al., 1995; Haschek et al., 1992; Jaskiewicz, Marasas, & Taljaard, 1987; Osweiler et al., 1993; Ross et al., 1993; Voss, Norred, Plattner, & Bacon,1989) as well as species-specific target organ toxicity, such as lung in pigs (Haschek et al., 1992), brain in horses (Ross et al., 1993), kidney in rats, rabbits, and sheep (Edrington et al., 1995; Gumprecht et al., 1995; Voss et al., 1989), and oesophagus in rats and pigs (Casteel, Turk, & Rottinghaus, 1994; Lim, Parker, Vesonder, & Haschek, 1996). Epidemiologic data has linked ingestion of corn contaminated with *F. verticillioides* to human oesophageal cancer (Rheeder et al., 1992), and fumonisins have been shown to be hepatocarcinogenic in rats and mice (Gelderblom et al., 1988; Howard et al., 2001). Both OTA and citrinin cause nephropathy in animals and they have also been implicated as the cause of Balkan endemic nephropathy in humans. Both OTA and citrinin are well-known nephrotoxins. OTA is also carcinogenic to rodents (Creppy et al., 1985) and possesses teratogenic (Arora, Frölén, & Fellner-Feldegg, 1983), immunotoxic (Størmer & Lea, 1995), neurotoxic (Bruinink & Sidler, 1997; Sava, Reunova, Velasquez, Harbison, & Sanchezramos, 2006), mutagenic (Stetina & Votava, 1986), and genotoxic (Meisner, Cimbala, & Hanson, 1983) properties. Compared to OTA, ochratoxin B is rarely found and very less toxic. Ingestion of clover hay containing slaframine causes salivary episodes that last from several hours to over 3 days in ruminants and horses (Gupta, 2007).

4. Factors affecting mycotoxins production and contamination of foods and feeds

Mycotoxins to human and animal health have multiple factors affecting production and/or presence of mycotoxins in foods or feeds. Hence, isolation and confirmation of mycotoxigenic fungal species in foods or feeds doesn't indicate the presence of mycotoxins. Upon development of accurate and sensitive techniques for qualitative and quantitative analysis of mycotoxins, researchers have found that various factors operation interdependently to affect fungal colonization and/or production of the mycotoxins. Factors that affect mycotoxins production and contamination can be categorized as physical, chemical and biological. Physical factors include environmental conditions conducive to fungal colonization and mycotoxin production such as temperature, relative humidity and insect infestation. Chemical factors include the use of fungicides and/or fertilizers. Biological factors are based on the interaction between the colonizing toxigenic fungal species and substrate (D'Mello & Macdonald, 1997).

5. Control of mycotoxins problems

Control of Mycotoxins is for the purpose of public health importance and economic improvement in the country. Hence, a number of strategies for reduction and control of mycotoxins have been considered in different areas of world including African countries. The control of mycotoxins in Africa involves: 1, Prevention of mould or fungus growth in crops and other feedstuffs; 2, Decontamination of mycotoxin contaminated feeds/foods as a secondary strategy; 3, Continuous surveillance of mycotoxins in agricultural crops, animal feedstuffs and human food.

5.1. Prevention of mould or fungus growth in crops and other feedstuffs

It could be achieved by following strict hygienic precautions during harvesting, storage and processing of agricultural crops and feedstuffs. Early harvesting of groundnuts resulted in lower Aflatoxin levels (Rachaputi, Wright, & Krosch, 2002). Proper drying and storage of crops are effective tools for reduction of mould growth and mycotoxin production. According to a trail in Guinea focused on through drying and proper storage of groundnuts, and it achieved a 60% reduction in mean Aflatoxin contamination levels (Turner et al., 2005).

5.2. Decontamination of mycotoxin contaminated feeds/foods

Includes physical, chemical and biological approaches. Physical approaches enlist as sorting, washing and crushing combined with de-hulling of maize grains, were effective in removal of Aflatoxin and Fumonisin in Benin (Fandohan, Gnonlonfin, Hell, Marasas, & Wingfield, 2005). Chemical approaches are the activities incorporating application of fungicides such as prochloraz, propiconazole, epoxyconazole, tebuconazole, cyproconazole, Oltipraz, chlorophylin and azoxystrobin for reduction of Fumonisin and Aflatoxin contamination (Haidukowski et al., 2005; Hayes et al., 1998; Ni & Streett, 2005). Biological approaches depend on the development of atoxigenic fungi that compete with toxigenic fungi in the environment. Introduction of atoxigenic strains of *A. flavus* and *A. parasiticus* to soil of developing crops resulted in 74.3 to 99.9% reduction in the Aflatoxin contamination of peanuts in USA (Dorner, Cole, & Blankenship, 1998).

5.3. Continuous surveillance of mycotoxins in agricultural crops, animal feedstuffs and human food and awareness creation

It is a long term intervention strategy which has been advocated by World Health Organization (2006) and James (2005). It is attractive for African countries to strengthen a nationwide surveillance, increase food and feed inspections to ensure food safety and local education and assistance to ensure that food grains and animal feeds are harvested correctly, dried completely and stored properly. This could be achieved through awareness creation on the areas of what danger mycotoxins are posing to human and animal health and productivity. It could be performed through government bodies, private organizations, and national media networks interms of newspapers and magazines as well as preparation of seminar and workshop that are used as avenue and bridge of information exchange and dissemination between researchers and peoples.

6. Conclusion and recommendations

Mycotoxins are poisonous chemical compounds produced by certain fungi. There are five mycotoxins or groups of mycotoxins that occur quite often in food: deoxynivalenol/Nivalenol, zearalenone, ochratoxin, fumonisins and aflatoxins. The fungi that produce mycotoxins in food fall broadly into two groups: those that invade before harvest, commonly called field fungi, and those that occur only after harvest, called storage fungi. There are three types of toxicogenic field fungi: plant pathogens such as *F. graminearum* (deoxynivalenol, nivalenol); fungi that grow on senescent or stressed plants, such as *F. moniliforme* (fumonisin) and sometimes *A. flavus* (aflatoxin); and fungi that initially colonize the plant before harvest and predispose the commodity to mycotoxin contamination after harvest, such as *P. verrucosum* (ochratoxin) and *A. flavus (*aflatoxin). The favourable conditions for mycotoxins production are instigate with poor hygienic conditions at the time of transportation and storage, high temperature and moisture content and heavy rains. Therefore, the following points should be forwarded as recommendations:

- Further study on the occurrence, economic and public health importance of mycotoxins should be undertaken.
- Owners or farmers should aware about mycotoxins and its impact and sources.
- Mycotoxins levels regulation should be implemented in African countries particularly in Ethiopia by government jurisdictions.

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