Review Article

Public Health Impact of Aflatoxin

Abstract

Aflatoxin is a naturally occurring food contaminant. The aflatoxins produced by aflatoxic fungi include B1, B2, G1 and G2, as well as two extra metabolic products, M1 and M2, which are significant as food and feed contaminants. The presence of aflatoxins in foods is also affected by insect activity, poor timing of harvest, heavy rainfall at harvest and post-harvest and inadequate drying of the crop before storage, as well as humidity, temperature, and aeration in the drying and storage process. This study aims to review the potential effects of aflatoxin on public health. People can be exposed to aflatoxins directly through consumption of contaminated foods or indirectly through eating foods derived from animals previously exposed to aflatoxins in feed. A contaminated aerosol can be inhaled as another exposure route. It has been reported that aflatoxin affects multiple organs and systems in the body. For a compound to be toxic, it has to undergo bio activation, which is mainly performed in hepatocytes. Bio activation is required to be toxic and this processing predominantly occurs in hepatocytes. According to the type, period and amount of exposure, toxicological effects include immunosuppression, impaired growth, and various types of cancer. Symptoms and the history of the individual (eating contaminated foods) are the most reliable diagnostic aids for aflatoxicosis. There is no specific antidote for aflatoxins. In addition to pre- and postharvest contamination, aflatoxin control should extend to all stages of the value chain. Because of their high toxicity and carcinogenicity, aflatoxins are a significant problem and among all the mycotoxins that cause worldwide contamination of foods and feeds. It is crucial to create awareness about aflatoxin contamination, its effect and its management.

Keywords: aflatoxin, cancer, public health

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Abbreviations: AFB, aflatoxin; GIT, gastro intestinal tract; HCC, hepatocellular carcinoma; LC, liquid chromatography; PDA, potato dextrose agar; ROS, reactive oxygen species; TLC, thin layer chromatography; WHO, World health organization

Introduction

In the past few years, mycotoxin contamination of food, feed, and agricultural products has become a serious concern since these toxic substances may cause various forms of poisoning and hence, diverse health problems in both animals and humans. There are mycotoxins in all kinds of food and agricultural products around the world. A toxigenic fungus is one that produces one or more mycotoxins. Mycotoxins are secondary metabolites that are produced by toxigenic fungi.[1] *Aspergillus*, *Fusarium*, and *Penicillium* are the three the most important genera of fungi that produce mycotoxins.[2]

There are four major aflatoxins produced by aflatoxins-producing fungi: B_1 and B_2, G_1 and G_2, plus two other metabolic products, M_1 and M_2, which are significant as direct contaminants of food and feed. Aflatoxin B_1 (AFB_1) can cause carcinogenesis, mutation, teratogenicity, and immune suppression in animals and humans. More than 100,000 turkey poultry in England (turkey X disease) were destroyed by aflatoxins in the early 1960s. Food and feed are often contaminated with carcinogenic toxins that pose a health and economic risk in many countries. Kenya reported an outbreak of jaundice in April 2004 with a high case-fatality rate. 317 cases and 125 deaths were caused by aflatoxin poisoning from eating contaminated homegrown maize.[3]

Food is frequently contaminated with aflatoxins, which are fungal secondary metabolites. Aflatoxins can negatively affect human health, food security, and economic trade in much of Sub-Saharan Africa. Because aflatoxins naturally occur in agricultural products, mycotoxins are important in developing countries with poor infrastructure, harvesting, and storage/storage methods for foods. The aflatoxins contaminate various agricultural commodities such as maize and peanuts at different stages of the food chain, either pre- or post-harvest, or may be excreted in hydroxylated form in milk or milk products. Food commodities such as maize, oilseeds, spices, groundnuts, tree nuts, milk, and dried fruit can be colonized by *Aspergillus flavus* and *Aspergillus parasiticus*.[4]

Over 5 billion people in developing countries are estimated to be at risk of chronic exposure to aflatoxins through contaminated food.[5] Those who live in these regions are more likely to be exposed to aflatoxins due to a lack of food supply and a lack of variety in food. A number of factors contribute to the occurrence of aflatoxins in foods, including insect activity, poor harvest timing, heavy rains at harvest and post-harvest and inadequate drying of the crops before storage. Humidity, temperature, and aeration are also important factors. Due to their high consumption rate worldwide and susceptibility to aflatoxin contamination, maize and peanuts are the main sources of aflatoxin exposure in humans. Humans can be exposed to aflatoxins either directly or indirectly through ingestion of contaminated foods or via consumption of animal feed contaminated with aflatoxins. Inhalation of contaminated airborne aerosols may also pose a risk, although this route has not been extensively investigated.[6]

In Ethiopia, dairy farmers commonly use mixed concentrate feeds containing traditional brewery by-products ("atela"), wheat bran, noug cake (*Guizotia abyssinica*), maize grains, and silage to increase production. These factors increase the risk of human exposure to AFM_1 contamination of milk.[7] In developing countries, fresh milk is often consumed without treatment posing a high risk to consumers. In developing countries, food systems and economics make developed-country approaches to the management of aflatoxins impractical. However, using food additives to protect farm animals from the toxins may also provide new effective and economical solutions to protect human populations. In developing countries, food systems and economics make developed-country approaches to the management of aflatoxins impractical. However, using food additives to protect farm animals from the toxins may also provide new effective and economical solutions to protect human populations.[8] Therefore, the objectives of this manuscript are to review the potential effects of aflatoxin on public health indicate possible effective prevention and control measures.

Literature review

Impact of aflatoxin on public health

In addition to death, acute aflatoxicosis leads to exacerbated malnutrition, which has catastrophic effects on affected populations. Lactating animals are excreting aflatoxin metabolites in their milk when fed aflatoxin-contaminated feed. As a result, consumers of milk may develop aflatoxicosis. It is for this reason that government regulations specify that milk must be free of aflatoxin. Nevertheless, no action is taken until the aflatoxin level in market milk exceeds 0.5ppb, below which the public is not at risk. A livestock's "action level" refers to the level of contamination at which the feed may be harmful to their health or cause contamination of milk, meat, or eggs.[9] Various factors can influence aflatoxin related diseases in humans, including age, sex, nutritional status, and contamination with other causative agents such as hepatitis B or parasites.[4]

Etiology of Aflatoxin

Four species of Aspergillus produce aflatoxins. Agronomically and economically most important aflatoxin producers are closely related *A. flavus* and *A. parasiticus. Aspergillus nomius* and *A. tamari* are also in this family. The fungi are soil-borne and grow on living and decaying plant matter. *Aspergillus flavus* is distinguishable from *A. parasiticus* from its smooth spores and yellow-green colonies on Potato Dextrose Agar.[10]

Around 25% of the world's crop is affected by mycotoxin, most of which is aflatoxin. Many spices, cassava, cottonseed, chili peppers, maize, wheat, millet, peanuts, rice, sesame, and sunflower seeds are commonly contaminated with these parasites. There are two ways that crops can become contaminated: Crops are infected by *Aspergillus* species during growth and development. In conditions of extreme heat, humidity, or drought, contamination can build up during storage or transportation.[11]

The epidemiology of human aflatoxicosis

Aflatoxin is mainly found in developing countries, where approximately 4.5 billion people live. Aflatoxin exposure is particularly harmful to children. The condition is associated with growth retardation, developmental delays, and liver damage that eventually lead to liver cancer. There is a correlation between aflatoxin exposure and growth stunting in children, according to many reports. There are epidemiological studies underway to determine the causal relationship between aflatoxin exposure and growth stunting. While adults are more tolerant of Aflatoxin exposure than children, children are still at risk. Aflatoxin exposure is believed to be responsible for 4.6% to 28.2% of all global cases of HCC. The death rate for high-dose exposure is around 25%. Children and those with Hepatitis B Virus (HBV) or Hepatitis C Virus (HCV) infections pose the greatest risk of aflatoxin exposure.[12]

Major Sources of Human Exposure to Aflatoxin

Aflatoxin from contaminated animal products

In terms of mycotoxins and food safety, we should focus on aflatoxins that are known to be transferred from feed to animal products, since these foods represent a significant route for human exposure.[13] If animals eat infected grains, aflatoxins will be detected in eggs, meat, and milk. The aflatoxin B1 product AFM1, which is produced during aflatoxin metabolism, can also be detected in milk in areas exposed to high levels of aflatoxin. Aflatoxin can be ingested by humans through consumption of milk or dairy products, such as breast milk and yoghurt, mostly in areas where animals are fed poor quality grains, including livestock.[14]

The greatest threat to human health over time has been aflatoxin contaminated milk, since cows and goats (major producer of drinking milk) are largely affected by contaminated forage around the world. Aflatoxin M_1 and M_2 (named after milk aflatoxins, and related to meat aflatoxins too) are thermo-stable hydroxylated metabolites created when lactating animals consume contaminated feeds containing aflatoxin. Livestock metabolizes ingested AFB1 and AFB_2 respectively, and the conversion rate is estimated to be 1–3% between AFM_1 and AFM_2.[15] Within 12-24 hours after consuming contaminated food, cows can transform AFB_1 in to AFM_1. AFM_1 residues can be found in milk six hours after ingestion, and the highest levels are reached a few days later. After 72 hours, the level of AFM_1 in milk is undetectable when AFB_1 intake is discontinued.[16]

Aflatoxin from contaminated grains

It is rare to find aflantoxin or ochratoxin residue in meat. Nevertheless, the disease is more prevalent in organs, particularly the liver. Animal tissues absorb much smaller amounts of AF. There are toxicologically significant levels of aflatoxin in fresh and processed meat (especially liver and kidney) in Egypt (up to 325µg/kg). Additionally, animal visceral organ consumption may be a more important source of exposure to AF than muscle consumption. The liver in swine, chicken and beef cattle is critical organ; i.e. before Aflatoxins are detected in other organs, they are already found in the liver in a rate of 0.1% of the amount of toxins consumed with the feed. Egg production is affected by hens' exposure, either long-term or short-term, through their diet.[17] (Table 1)[18]

Table 1 Aflatoxin residues from contaminated feed in animal products[18]

Animal	Source Aflatoxin	Percentage level	Critical concentration in feed	Feed tolerance limit
Dairy cattle	Milk/M1	0.3%	30 ppb	10 ppb single feed
Swine	Liver/B1	0.1%	80 ppb	10-20 ppb
Hen	Liver/B1	0.1%	100 ppb	10 ppb for chicks, 20 ppb for broilers
	Eggs/B1	0.05%	220 ppb	20 ppb for layer
Beef cattle	Liver/B1	0.01%	1400 ppb	10 ppb for calf, 20 ppb for adult

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Agricultural crops can be infected before, during, or after harvest. The pre-harvest infestation of food crops with aflatoxin is mostly found in tree nuts, acha, cottonseed, wheat, peanuts, maize, etc. Post-harvest contamination is found in many other agricultural products including rice, spices, as well as coffee. Inappropriate storage of food crops in conditions, such as warm and humid storage environments, which favour the growth of mould, can typically result in contamination levels much higher than the ones found in the field.[19] Due to their greater susceptibly to contamination and frequent consumption around the world, corn and groundnuts are major human exposure sources. The most common source of aflatoxin is contaminated grains and thereby products.[20]

Mechanism of Action

Aflatoxin species are all lipolytic in nature and absorbed across cell membrane from the site of exposure, such as the gastrointestinal tract (GIT), respiratory tract and enter into the bloodstream, where they are carried to various tissues and to the liver. To be toxic, AFB_1 must undergo bio activation, which occurs predominantly in hepatocytes. The small intestine especially duodenum is where AFB_1 is initially absorbed. In the liver, they are metabolized to reactive epoxide intermediates or hydroxylated to less toxic aflatoxin M_1. In humans and susceptible animals, the cytochrome P_{450} enzyme converts AFB_1 in to an epoxide, which binds to DNA and albumin in the blood causing DNA damage. Hepatocarcinogenesis occurs when the epoxide binds to mitochondrial DNA. The binding of AFB_1 to DNA at the guanine site in liver cells affects the genetic code of enzymes that control cell proliferation. Tumors form as a result of this process. By forming adducts with DNA, RNA and proteins, aflatoxins bind and interfere with enzymes and substrates necessary for initiation, transcription, and translation process in protein synthesis.[21]

Aflatoxin' s effects on human organs and systems

Aflatoxin and hepatic injury

There is evidence that aflatoxins can cause liver cirrhosis and liver cancer. Globally, HCC is one of the most prevalent and life-threatening cancers. AFB_1 causes a reduction in total protein levels in both the liver and kidney, where aflatoxins are known to impair protein synthesis by forming adducts with DNA, RNA and proteins; inhibit RNA synthesis and degranulate the endoplasmic reticulum. As a result of acute liver injury due to aflatoxin, serum enzymes were including aspartate aminotransferase, lactate dehydrogenase, glutamate dehydrogenase, gamma glutamyl transferase, alkaline phosphatase, and bilirubin rise, reflecting liver damage as well as other biochemical changes including proteinuria, ketonuria, glycosuria, and hematuria. As a result of chronic liver failure, metabolites such as ammonia and fatty acids accumulate in the bloodstream, resulting in brain damage and hepatic encephalopathy.[22]

Gastro intestinal tract effect of Aflatoxin

Consumption of aflatoxins-contaminated foods, especially AFB_1, results in aflatoxins entering the GIT. In addition, it is the primary route for the excretion of aflatoxin metabolites from the bile. Human colon cancers, such as colon carcinomas, may be caused by aflatoxins, metabolities, and AF-8, 9-epoxide. There is evidence that aflatoxins play a role in the development of gastrointestinal and liver tumors among Africans, Filipinos, and Chinese.[23] Diarrhoea, vomiting, intestinal hemorrhage, liver necrosis, and liver fibrosis have been reported as side effects of aflatoxin.[24]

Urinary System Effects

A large amount of circulating toxicants reach the kidney due to the high amount of blood it receives and about twenty-five percent of the blood that flows into the kidney at rest. Different parts of the nephron are exposed to aflatoxins, including AFB_1 and its metabolites, which lead to nephrotoxicity before it is excreted in the urine. Aflatoxin-induced reductions in protein content can be explained by increased necrosis of the kidney. AF also decreases glomerular filtration rate, tubular glucose reabsorption, and pamino hippurate tubular transport.[22]

Respiratory system effects

One of the only systems of the body with vital elements in constant contact with their surrounding environment is the respiratory tract. People who work in the food industry as their occupational setting are often exposed to aflatoxins, particularly AFB_1, when they inhale Aflatoxin contaminated dusts, such as during grain shelling and processing, and are reported to have higher incidences of upper respiratory tract and lung cancer. When lung cells are exposed to polycyclic aromatic hydrocarbons, cytochrome P_{450} are induced, which may activate AFB_1. On human lung tissue fractions, a study was conducted to investigate the possible role of other oxidative systems in the activation of AFB_1 and its deactivation by glutathione transferase.[25]

Reproductive system effects of aflatoxin

Aflatoxin concentrations in the semen of infertile men are higher after chronic exposure to aflatoxin-contaminated foods.[26] It has been suggested that aflatoxins can inhibit enzyme synthesis, fatty acid metabolism, and production of sex hormone precursor molecules in the liver. There has also been evidence that aflatoxins cause a direct lysis of the sperm cell membrane, resulting in the loss of lysozyme, an enzyme that helps spermatozoa penetrate the ova.[27]Aflatoxin also causes pathological changes in the form of coagulative necrosis, particularly in follicles that are growing and mature as well as a decrease in the number and size of graftines and growing follicles, as well as a small area of degeneration. Additionally, it has been linked to low birth weight, which poses a risk of infant jaundice, as well as AFM in breast milk, which can negatively affect newborns.[28]

Effects on nervous system

Some compounds damage neurons or neurotoxic and thus inhibit their function. Mycotoxins especially aflatoxins and its metabolites and other products such as the Reactive Oxygen Species (ROS) like the AFB-8,9-epoxides may interfere with the normal functioning of the nerve cells by forming DNA adducts, protein adducts, oxidative stress factors, mitochondrial directed apoptosis of the nerve cells as well as inhibiting their synthesis of protein, RNA and DNA.[29] Aflatoxins also cause abnormalities in mitochondrial DNA, structure and function, including defective oxidative phosphorylation in the brain cells. Deficiencies in these neurotransmitter lead to neurological symptoms such as neurocognitive decline and alteration of sleep cycle and symptoms of brain damage like dullness, restlessness, muscle tremor, convulsions, loss of memory, epilepsy, idiocy, loss of muscle coordination, and abnormal sensations.[30]

Effects on immune system

Humans and animals worldwide have been reported to be immunosuppressed by the chronic consumption of aflatoxin-contaminated foods.[24] Exposure to aflatoxin suppresses the immune system, particularly cell-mediated immunity responses. Chronic aflatoxin exposure has been associated with immune suppression and nutritional effects, contributing to high HIV prevalence. There is a correlation between weakened CD_4 proteins caused by aflatoxin exposure and HIV infection. Additionally, high aflatoxin levels have been linked to an increased risk of tuberculosis in HIV-positive individuals. As a result of aflatoxin exposure, parasitic, bacterial, and viral infections are more likely to occur.[31]

Symptoms of Aflatoxicosis in Human

Symptoms of acute high level exposure to aflatoxin include decreased appetite, malaise, and low fever; later symptoms, such as vomiting, abdominal pain, and hepatitis, indicate a potentially fatal liver failure. As a result of acute aflatoxicosis caused by extremely high levels of aflatoxin, the human body suffers hemorrhaging, acute liver damage, edema, and high mortality rates. Chronic low-level exposure to aflatoxin, in particular aflatoxin B_1, may lead to hepatocellular carcinoma, or liver cancer, malnutrition, and stunted growth in children.[24] The signs of aflatoxicosis are extremely diverse and most go undetected due to the chronic exposure and to cellular changes in various organs rather than a specific organ.[32]

Diagnostic Method

Because of variations in clinical signs and the presence of other factors such as suppression of the immune system due to infection, detecting aflatoxicosis in humans and animals is difficult. Diagnostic aids for aflatoxicosis include the history of the affected individual (eating contaminated foods) and symptoms (vomiting, diarrhea).[33]

Human chronic exposure to aflatoxin can be evaluated using two main methods. First, food samples are collected. The most commonly available data comes from food samples taken from prepared meals and ingredients or from markets. An analysis of prepared meals is the most reliable method for determining exposure levels, since people sort grain, removing those kernels that are deemed unfit for eating. Samples from the market and trade provide information on the risk of exposure to various foods in the diet, particularly when local food processors perform operations such as milling without quality control. In the second approach, biological markers of exposure are used. Aflatoxin derivatives are detected by obtaining blood, milk, or urine samples from humans and then analyzing them for their half-lives in the body. Food and feed aflatoxins are analyzed by Thin Layer Chromatography (TLC), Liquid Chromatography (LC), and Immunochemical Methods.[8]

Treatment of Aflatoxicosis

Prior to treatment, prevention is the best option. Aflatoxin toxicity has no specific antidote. On the other hand, timely administration of L-methionine (200mg/kg) and sodium thiosulfate (50mg/kg), at eight-hour intervals, has proven to be therapeutic. An increase in protein, vitamins, and antioxidants can also be beneficial. Chemo protection and/or enterosorption can be used to minimize aflatoxins' biological impact. Several compounds have been used as chemo preventives against aflatoxins (such as esterified glucomanoses and other yeast extracts) which either increased detoxification of aflatoxins or prevented the production of aflatoxin epoxide, thereby reducing or blocking AFB_1-induced hepatocarcinogenesis. To reduce the biologically effective dose, compounds such as oltipraz and chlorophyll are available.[31] Some zeolites are effective at removing ROS after absorption. In order to reduce the chance of secondary infections, good management practices are essential to alleviate stress. It is important to treat secondary infections as soon as possible. A food additive that binds aflatoxins and renders them biologically inaccessible to humans and animals is recommended.[34]

Prevention Measures and Intervention Strategies

Pre harvest intervention

Aspergillus growth on pre-harvested crops depends on the environment. Agricultural practices that reduce *Aspergillus* on pre-harvested crops include irrigation and pest management (Pre-harvest interventions include choosing crops resistant to abiotic stresses (like drought, temperature, and moisture content) and reducing crop stresses in general, developing host resistance through plant breeding, and choosing varieties genetically higher resistance to fungal growth, aflatoxins production, diseases, and pests.[35]

Post-harvest intervention

To prevent the development of aflatoxins, crops should be properly dried before being stored. Physical methods are both less expensive and less risky than chemical methods for reducing aflatoxin accumulation after harvest. Immediately following harvest, physical sorting enables the removal of the most contaminated foods. Using the post-harvest intervention package described in which sorting, wooden drying pallets, natural-fiber storage bags, and insecticides are used, aflatoxin-induced HCC was significantly reduced without significant health or environmental risks. Aflatoxin can be destroyed by chemical methods such as ammonization and ozonation, which are relatively inexpensive.[36]

Dis infection method

The best anti-fungal compounds found in feed were propionic acid, sodium propionate, benzoic acid, and ammonia, followed by urea and citric acid. It has been found that compounds used for seed fumigation, such as ethylene oxide and methyl bromide, significantly reduced the incidence of fungi on stored ground nuts and melon seeds.[37]

Reduction through food processing procedure

It is possible to remove contaminated food from food preparation or consumption, dilute contaminated food with uncontaminated food, neutralize aflatoxins present in food, or alter the bioavailability of the aflatoxins consumed. Cooking temperatures are not largely responsible for the reduction of aflatoxin levels, however simple cooking methods like sorting, washing, crushing, and dehulling do.[38]

Economic Importance

As a result of a lack of good data, the magnitude of the economic impacts of aflatoxin contaminated food consumption in developing countries is unknown. By quantifying economic losses and estimating the health effects of aflatoxin, they believe that Health Ministries will be encouraged to enforce standards and provide advocacy to benefit rural populations who are less educated about aflatoxin exposure. Aflatoxin's economic impact is directly attributed to crop losses and livestock losses, and indirectly due to the cost of regulatory programs designed to reduce the risks to animal health and human health. Food contamination with aflatoxin results in financial losses and economic damage to agriculture and animal husbandry, as well as major pharmaceutical and medical costs for treating food poisoning.[7]

Status of aflatoxin in Ethiopia

Ethiopian scientists have studied mycotoxins for over four decades, with the first AFs study published in 1981. Several researchers have since reported the presence of mycotoxins in diverse food and feed commodities. According to a recent survey of 90 maize grain samples from the West Showa and East Wallega zones, *Aspergillus* species dominated. Additional detections of AFB_1 ranged between 3.9 and

381.6 g/kg. Ethiopians' daily food also contains spices and mixes that are contaminated with AFs. 'Shiro' is consumed by all Ethiopians, so detecting AFB_1 in it is of concern. A variety of spices and legumes are mixed together to make shiro. Ethiopian barley, sorghum, wheat and teff contain mycotoxins caused by *Aspergillus* and *Fusarium*. Chronic aflatoxin exposure led to approximately 11–288 cases of HCC in Ethiopia, and the synergetic effects of AFs and HBV were responsible for 21–643 cases, with chronic HBV prevalence in Ethiopia being among the highest among African countries (6–7%).[39]

In Ethiopia, groundnut samples have been contaminated to an extent much higher than international, FAO and WHO standards (which are 15 g/kg). An investigation of the aflatoxin content of groundnut (*Arachis hypogaea*) in relation to the shelling and storage practices of Ethiopian farmers was conducted. Aflatoxins were detected in 80.69% of the total samples analyzed by *Aspergillus flavus*, the most potent aflatoxigen.[40]

Conclusion and recommendation

The world, especially in Africa, is experiencing an increase in the risk of aflatoxin contamination of commodities. The principal way humans are exposed to aflatoxins, both unconjugated and conjugated, are by consuming plant-derived and milk products contaminated with these compounds, which are resistant to heat within the range of conventional treatment temperatures. The principal way humans are exposed to aflatoxins, both unconjugated and conjugated, are by consuming plant-derived and milk products contaminated with these compounds, which are resistant to heat within the range of conventional treatment temperatures. The most common source of aflatoxins is contaminated grains and their by-products. Apart from their toxicological effects on affected animals, aflatoxin contamination can also affect humans through animal derived products, including meat, milk, and eggs. In terms of introducing aflatoxin residues into the human diet, milk has been shown to have the greatest risk. Aflatoxins have been reported to affect a variety of body organs, such as the liver, kidneys, lungs, brain, testes, and heart. As a major health and economic problem, aflatoxins and their associated health disorders in humans have been recognized, which dictate measures to minimize exposure by implementing appropriate agricultural practices, storing products and monitoring products intended for human or animal consumption. In addition, creating awareness about aflatoxin contamination, its effects, and its management is essential. Therefore; it is recommended that the following measures be taken based on the above conclusion:

- Choosing drought-resistant, disease-resistant, and pest-resistant crops is important to farmers.
- Support and strengthen research and technology transfer on aflatoxins and its management. Public training on better agriculture, hygiene, preservation and storage of food should be undertaken.
- Strong collaboration between ministry of agriculture and ministry of health should be encouraged.
- Encouraging better livestock feeding and management practice.
- Increase public awareness and stimulate demand for aflatoxin-safe food and feed.

Data Availability

The data sets that support these finding are available from the principal author up on request.

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Authors' contribution

All authors contributed to data analysis, draft writing, gave final approval of the manuscript version, we agree to publish in the submitted journal, and we will be responsible for all aspects of the work.

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Conflicts of interest

The authors have no conflict of interest.

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