Chapter 7

Incidence and Chemical Implications of Aflatoxin in Street-Vended Foods

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Abstract

It is known that aflatoxin is produced by some *Aspergillus* fungal strains. Incidence of this toxin in food and feeds is as a result of contaminations by these fungal strains. *Aspergillus* strains are common in human environment, and their effects on foods are issues of global concern. First, we need an adequate knowledge of aflatoxin, then we can design proper control and regulatory strategies for its control. In this chapter, we present importance of street-vended foods and their possible health risk on the populace due to possible aflatoxin contamination; we took insights into types and incidences of reported aflatoxin contaminations in street-vended foods and reviewed the chemical nature, structures, and metabolism of aflatoxins and their actions as chemical poisons to human (mycotoxicosis) with deep insight into their toxicology. In addition, we review different environmental factors that may affect aflatoxin production in foods and also considered economic impact of aflatoxin contaminations of foodstuffs. In this chapter, we also discussed different aflatoxin aflatoxin detection methods in foods and examined available or possible regulations to best control its incidence in street-vended food. Adequate understanding of these important information about aflatoxin will form a bedrock for its control in street-vended food.

Keywords: incidence, implication, aflatoxicosis, toxicity, street vended

1. Introduction

Mycotoxins are secondary metabolites of molds (low-molecular-weight organic compounds) that have adverse effects on human, animals, and crops resulting in various illnesses, termed as mycotoxicosis [1]. Mycotoxins are colorless, odorless, and tasteless compounds with diverse characteristic structures and molecular weight, examples are deoxynivalenol (DON), fumonisins, ochratoxins, patulins, zearalenols, trichothecenes, and so on, but the most common of them are the aflatoxins. The name "aflatoxin" is known as toxins that are produced by *Aspergillus* species especially the *Aspergillus flavus* and *Aspergillus parasiticus*; however, other fungi that have recently been reported to be able to produce aflatoxins are *A. nomius*, *A. pseudotamarii*, and *A. bombycis*. Aflatoxins are difuranocoumarins in nature, and they are of different types such as aflatoxin B_1 (AFB_1), B_2 (AFB_2), G_1 (AFG_1) and G_2 (AFG_2), M_1 (AFM_1), and M_2 (AFM_2), another 18 groups of closely related aflatoxins have been detected in agricultural products and different street-vended foods especially stored grains [2, 3].

Street-vended foods are very important to human health as many people derive pleasure in quick ready-to-be-eaten food without stress especially on the road, streets, and other public places due to their unique flavors and conveniences. Most people that are involved in street food vending are the poor and the lower class people, most of whom are ultimately aimed in getting profit other than meeting people's needs, and some hygienic handlings might be too expensive; they are therefore capable of spreading food-borne diseases if not hygienically handled, and aflatoxins are one of the most frequently reported toxins in street-vended foods.

Aflatoxin contamination of foods can, however, occur at different points in the food chain depending on the time of mold's evasion. It may be produced during preharvest, harvest, drying, or storage period but ultimately depends on the method and handlings, packaging, or transport conditions of the food materials. Once any of the conditions favor the fungal growth, aflatoxins may be secreted. Rice and Ross [4] reported that FAO estimated that approximately 25% of the world's cereal products are contaminated with mycotoxins. Rapid urbanization and population growths increase the labor force, and demand for survival with these street food trades gained its momentum. Majority of the population and labor force belong to the lower class group, and the street food trade is becoming viable informal-sector industry especially for the developing entrepreneurs. Consequently, people residing in aflatoxin-endemic countries are more reported with increased incidence of acute hepatic necrosis, resulting later in cirrhosis, or hepatocellular carcinoma, and this may be increasing due to different cultural systems of food preparation and storage [2, 5–8].

However, when considering different production methods adopted for different street-vended foods, it becomes very important to understand the chemical and health implications of aflatoxin contamination of these foods above stipulated limits and with this, we would be able to design adequate control measures against aflatoxin occurrence in the street-vended foods. Many countries have enacted regulations to prevent mycotoxins in foods due to their effect on human's heath and the world trade, according to the annual report of the Rapid Alert System for Food and Feed (RASFF) [9], mycotoxins were the main hazard in border rejection notifications in the European Union (**Table 1**).

Mycotoxin	2008	2009	2010	2011	2012	Total
Aflatoxins	902	638	649	585	484	3258
Deoxynivalenol (DON)	4	3	2	11	4	24
Fumonisins	2	1	3	4	4	14
Ochratoxin A	20	27	34	35	32	148
Patulin	3	–	–	–	–	3
Zearalenone	2	–	–	–	4	6
Total	933	669	688	635	525	3450

Table 1. Annual reports on mycotoxins from EU countries by Rapid Alert System for Food and Feed (RASFF) [11].

2. Street-vended foods and aflatoxin incidence

Street food vending can make good contribution to the economy of developing countries, for example, the Indian National Policy for Urban Street Vendors/Hawkers reported street vendors of about 2% of the metropolis population [10, 11]. However, street-vended foods are perceived to pose some major public health risks mostly in developing countries, and this is due to unavailability of basic infrastructures and difficulty in controlling large number of food-vending operators. There are several reported incidences of food poisoning due to consumption of street-vended foods. For example, the Shandong Province in China has recorded about 691 outbreaks of food poisoning from vended foods which are responsible for over 49 deaths during the period of 1983–1992 [12–19]. Aflatoxins are mostly reported in stored cereals, legumes, and nuts, and their derivatives (European Food Safety Authority (EFSA) report [20]). Marin et al. [21] stated that different aflatoxin contents were detected in 34,326 food samples from different European Union countries (**Table 2**) and also in some food materials from African and Asian countries; selected examples are presented in **Table 3**.

Insufficient drying and humid storage environmental conditions may result in high mood invasion and concurrent aflatoxin contamination of foodstuffs. Aflatoxin contamination of street-vended foods is of a great concern especially when it occurred above the tolerance limit. Aflatoxin outbreak, such as the Kenya 2004 and 2005 aflatoxin outbreak from locally stored maize [22], may also have economic implications. Therefore, there is a need to recognize the aflatoxin biosynthesis associated with different handlings of street-vended foods as to human tolerance levels of these aflatoxins. Some countries already developed some specific regulations against aflatoxin contaminations with tolerance limit for aflatoxin B1 in foodstuffs ranging between 0 and 30 μg/kg and total aflatoxin contents of 0–50 μg/kg (worldwide regulations for mycotoxins in food and feed in 2003 [23]). However, prevention of disease in street-vended food in many developing countries was difficult due to uncontrollable environmental factors. The street vendors did not have significant knowledge of epidemiology and their safety measures.

Food category	No. samples	No. samples > LOD	Median AFB1/AFT	Mean AFB1/AFT	Maximum AFB1/AFT
Almonds	1766	471 (27%)	0.20/0.28	1.46/1.82	575/579
Brazil nuts	622	271 (43%)	0.20/0.40	22.2/39.6	1897/3337
Hazelnuts	3163	940 (30%)	0.16/0.30	0.95/1.70	200/200
Cashews	336	33 (10%)	0.10/0.20	0.42/0.60	36/39
Peanuts	8929	1830 (20%)	0.10–0.20	1.93/2.69	935/985
Pistachios	4069	1783 (44%)	0.20/0.40	16.8/19.4	2625/2680
Other nuts	1131	158 (14%)	0.10/0.20	1.16/1.41	385/402
Figs	2067	618 (30%)	0.15/0.24	1.36/2.22	130/151
Other dried fruits	1396	114 (8%)	0.10/0.24	0.26/0.51	20/90
Maize	943	136 (14%)	0.12/0.24	0.26/0.41	8/9
Other cereals	3010	207 (7%)	0.20/0.40	0.35/0.51	109/117
Spices	4698	1988 (42%)	0.20/0.40	1.46/1.88	96/96
Baby foods	592	23 (4%)	0.02/0.04	0.07/0.14	1/2
Other foodstuffs	1604	303 (19%)	0.10/0.20	0.53/0.75	99/99

Table 2. Detected aflatoxin contents in food sample (μg/kg) from different EU countries as reported by the European Food Safety Authority [23].

Country	Commodity	Mycotoxin	Level	Source
Saudi Arabia	Peanuts	Aflatoxins	28 μg/kg	[26]
Nigeria	Groundnuts	Aflatoxins	10–176 ppb	[27]
South Africa	Cowpeas	Fumonisins	0.6–25.30 μg/kg	[27]
Iran	Walnuts	Aflatoxins	14.4 ± 8.4 μg/kg	[29]
Iran	Peanut (roasted)	Aflatoxins	17.99 ± 18.70 μg/kg	[29]
Benin Republic	Cowpea	Aflatoxins	3.52 μg/kg	[28]
Nigeria	Yam chips	Aflatoxins	4–18 μg/kg	[25]
Nigeria	Maize	Aflatoxins	3–138 μg/kg	[31]
Nigeria	Shelled melon	Aflatoxins	5–20 μg/kg	[28]
Pakistan	Chili	Aflatoxins	0.1–96.2 μg/kg	[29]
Pakistan	Milk and sweets	Aflatoxin M1	0.05–0.48 μg/kg	[30]

Table 3. Mycotoxins contamination in some foodstuffs in Afro-Asia.

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3. Structures and aflatoxin metabolisms in humans

Aflatoxins were first isolated from the Turkish X-disease patients that consumed the mold-contaminated food as a result of production of aflatoxins. Later these toxins were also found in *Aspergillus* and few *Penicillium* species. These aflatoxins were present in food and dairy products. On the basis of fluorescence UV light, the aflatoxins were characterized as B_1, B_2, G_1, and G_2, while minor metabolites were also detected on the basis of thin layer chromatography (TLC) and were known as M_1 and M_2. Aflatoxins of different types have been reported in many street-vended foods, the most common ones are Aflatoxin B, G, and M. They are crystalline, soluble in polar solvents (methanol, chloroform, and water). They fluoresce when exposed to UV light. Ammonia and/or hypochloride solutions have been investigated for removal of aflatoxins in food materials as it is believed that the lactone ring can cause aflatoxin alkaline hydrolysis; however, the toxicity of this breakdown is still of a great concern. Aflatoxins B_1 and G_1 are usually converted into B_{2a} and G_{2a}, respectively, during catalytic acid interference leady to oxidize these toxins; this makes them lose their crystalline nature.

Aflatoxin B_1 is one of the potent, mutagenic, and carcinogenic toxins [32–35]. It was present mostly in conjugation with other aflatoxins like B_2, G_2, and G_1. Structurally, it consists of either five rings along with furofuran moiety or five aromatic carbon rings or six lactone rings. Another parasitical aflatoxin was produced from *Aspergillus* species which is known as B_2. It was first isolated and identified from *Aspergillus parasiticus*. Both B1 and B2 emit lights under UV fluorescence. B_1 and B_2 emit blue light [38]. M_1 and M_2 were minor metabolites produced by the B_1 and B_2 aflatoxins. These aflatoxins were formed when cows were fed with a fungal contaminated food. The most important carriers of M_1 and M_2 in cows are maize, cotton seed, ground nut, etc. M_1 and M_2 were produced in the milk of cow; hence, it is also known as cow milk aflatoxins. Structurally aflatoxins also consist of five/six aromatic or lactone rings along with the furofuran moiety but in the junction of carbon furan rings and the hydroxyl group as shown in **Figure 1**.

The chemical characteristics of these aflatoxins are presented in **Table 4**.

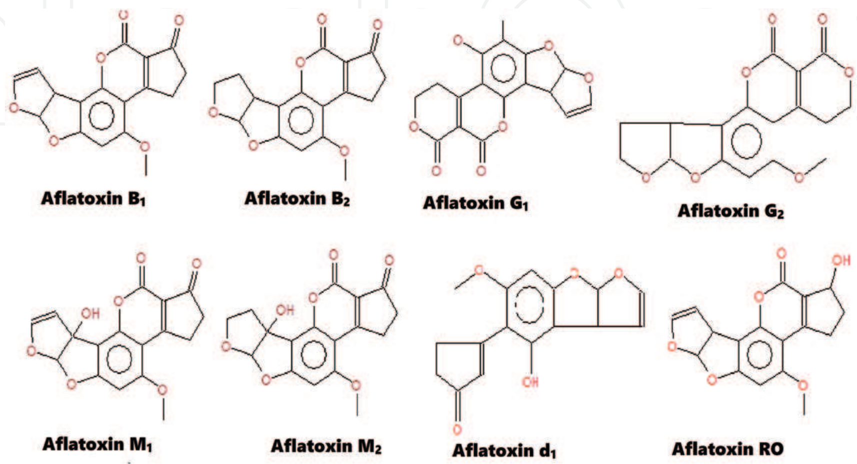

Figure 1. Structure of aflatoxins.

Metabolism of aflatoxins usually form many other metabolites, examples are aflatoxins R_0, RB_1, RB_2, and H. These aflatoxins have hydroxyl group in their ring's carbonyl group, D ring may also be formed in some other cases such as in aflatoxins RB_1 and RB_2 while an opened E ring may be formed in B_3.

Two pathways known for the formation of all these aflatoxins are:

1. Microbial transformation
2. Chemical reduction of sodium borhydride

Aflatoxins are highly toxic and carcinogenic. The disease caused by aflatoxins is known as aflatoxicosis. It mainly targets the liver of humans and animals. Toxicity of aflatoxins depends upon the number of factors such as age, sex, species, and national factors [24]. The aflatoxin metabolic pathways are well studied in animals, but in human, data was very limited. In rats, the DNA/RNA synthesis was inhibited by ingestion of aflatoxins (5 mg/kg). The B1 aflatoxin binds with the N_7 guanine by covalent bonding and formed AFB1-N7-guanine adducts. It results in the transversion of G to T which caused the DNA mutations and carcinogenic. In animals or in humans, the pathway of aflatoxins is described as in **Figure 2**. While in humans (AFB_1-N7-guanine)

Aflatoxin	Molecular formula	Molecular weight	Melting point	UV absorption max (e), nm, methanol	
				265	360–362
AFB1	$C_{17}H_{12}O_6$	312	268–269	12,400	21,800
AFB2	$C_{17}H_{14}O_6$	314	286–289	12,100	24,000
AFG1	$C_{17}H_{12}O_7$	328	244–246	9600	17,700
AFG2	$C_{17}H_{14}O_7$	330	237–240	8200	17,100
AFM1	$C_{17}H_{12}O_7$	328	299	14,150	21,250 (357)
AFM2	$C_{17}H_{14}O_7$	330	293	12,100 (264)	22,900 (357)
AFd1	$C_{16}H_{14}O_5$	286	250–300	11,200	20,120
AFRO	$C_{17}H_{14}O_6$	314	280–290	12,100 (310)	22,900 (320)

Table 4. Chemical characteristic of different aflatoxins.

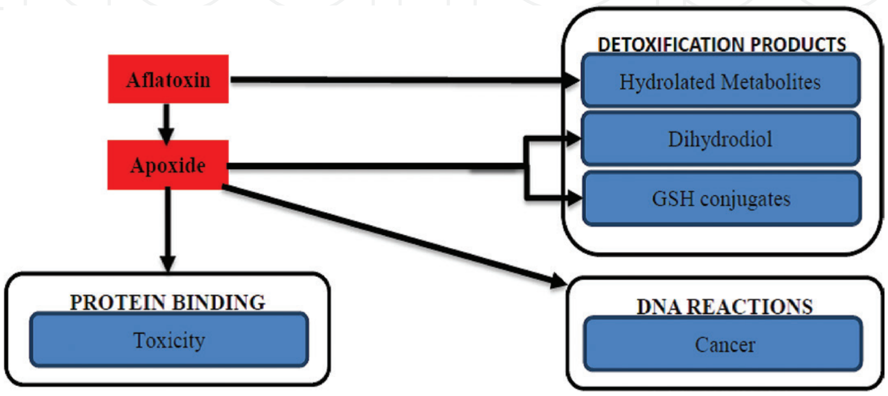

Figure 2. Aflatoxin metabolism in humans.

transverse the nucleotides G to T at the position of codan 249. These suppress the p53 tumor gene. The reactive epoxide formed which hydrolyzed to form AFB_1-8,9-dihydrodiol. The dihydrodiol ionizes and formed a Schiff's base with primary amine groups in the proteins. The AFB_1 also inhibits the phosphodiesterase activity in the kidney, liver, and brain [36].

4. Tolerance, detection, and aflatoxin action as chemical poison

In the 1980s, aflatoxin B1 and sum total aflatoxin tolerance level in foodstuffs range from 0 to 50 μg/kg. Some countries have a zero tolerance which practice the limit of detection depending on the analytical procedures and standards (**Table 3**), for example, Austria and Switzerland have the lowest tolerance limit for aflatoxin B1. And aflatoxin B1 is the most important aflatoxin, based on the occurrence frequency and its toxicity. For detection of many aflatoxins, thin layer chromatography (TLC) or high-performance liquid chromatography (HPLC) is commonly used, but in some cases, mini-column, gas chromatography/mass spectrophotometry and qualitative radioimmunoassay (RIA) methods may be adopted. These methods are frequently coupled with the analytical methods of AOAC or AOAC-derived methods. It may be expected here that the immunoassay detection such as the enzyme-linked immunosorbent assay (ELISA) method will also gain attention, but this methods is presently still undergoing intensive validation processes to be used as a generalized tool for regulatory analysis.

Aflatoxin acts as toxic secondary metabolites, carcinogenic, hepatotoxic, immunotoxic, and teratogenic in humans and many animal species. High ingestion and accumulation of 'aflatoxins' also pose toxic effects on human cell and tissues and even on genes. Aflatoxin poisoning is common in some areas of the world, and different types of this case have been documented. Many cases of aflatoxicosis have also been reported in Africa and Asia, most of which involve the ingestion of contaminated cereals such as maize, rice, or other foods like cassava or dried powdered food materials; some other cases were reported in food products such as pasta or peanut meals. An example of such case is the 1990 Malaysia aflatoxin infection of over 40 adult humans and 13 children deaths associated with the consumption of aflatoxin and borate contamination of noodles. The autopsies of the heart, brain, spleen, liver, kidney, and lung showed damages from aflatoxin interference. Autopsy of brain (cerebrum) specimens from 18 kwashiorkor children and 19 other children who had died from a variety of other diseases in Nigeria showed aflatoxin present in 81% of the cases [37].

5. Aflatoxins and mycotoxicosis (toxicology)

5.1. Effect of fungal toxins on humans

The human body could be exposed to mycotoxins through skin contact or by direct inhalation of spore-borne toxins, and these tend to accumulate within the body organs or tissues during their metabolism [24]. Infections caused by fungi such as *A. flavus* are known as *mycosis*, symptoms of high mycotoxin content in body cells is called *mycotoxicosis*, and diseases or symptoms of aflatoxin poison are referred to *aflatoxicosis*. Therefore, there is a high possibility that aflatoxins might play some important roles in mycotoxicosis. Mycotoxins are potent but silent killer endemic in most third world countries due to poor storage systems, leading to obnoxious levels of mycotoxins in food products [38]. These toxic compounds cause induction of jaundice, cancer, immune suppression, premature puberty in girls, reproductive dysfunction, birth defects, obstruction of liver metabolism, and liver cirrhosis by damaging DNA and sulfhydryl bonds in many enzymes [39, 40]; they also take part in gastrointestinal infection, kwashiorkor, Reye's syndrome, and hepatitis. Aflatoxin B1, for example, may cause chromosomal aberration in human. Generally, when aflatoxins B1, G1, and M1 are accumulated in human tissues, it results in epoxide formation at eight and nine positions in the terminal furan ring and then binds covalently with the nucleic acid.

Diagnostic features of mycotoxicosis:

1. Non-transmissible.
2. Seasonal outbreak.
3. Disruption associated with specific foodstuff.
4. Drug treatments have little or no effect.

5.2. Aflatoxins and aflatoxicosis

Many aflatoxins can cause acute mycotoxicosis (i.e., when the symptoms show within a short period after infection say like 7 days, it may lead to death if not treated on time) and/or chronic mycotoxicosis (i.e., when they appear and persist for a long period of time). In 1993 International Agency for Research on Cancer (IARC) has classified four types of naturally occurring aflatoxins AFs (AFB_1, AFB_2, AFG_1, AFG_2) as the most active substances that cause mutagenicity and carcinogenicity [45]. Aflatoxin AFB_1 is the most prevalent among all types of aflatoxins due to long-term chronic exposure to even very small amount of aflatoxin in food items, and it is an important concern for human health [10]. Its chronic exposure can lead to malnutrition, suppressed immune response, centrilobular necrosis, proliferation of bile duct, hepatic lesions and fatty infiltration of liver, and even hepatomas [41, 42] as shown in **Figure 2**.

Symptoms of mycotoxicosis depend on the quantity or concentration of the toxin, time of exposure, type of the mycotoxin involved, degree of toxin combination, host resistant capacity, physiological status of the host, and so on. Mycotoxin can cause heath effect in contact with the skin and alimentary canal, by inhalation or by other means. The toxins can enter into blood streams and the lymphatic system to inhibit the process of protein synthesis, damage macrophage system, or affect the lung's ability to clear particles or cause immune suppression.

5.3. Hepatocellular carcinoma (HCC)

Carcinogenic chemicals like aflatoxin can bring different modifications in DNA sequence or protein structure which causes DNA adduct formation and finally cancer in effected people. AFB1 is a micro-component of nutrition that causes genetic alteration by inducing adduct formation, leading to DNA strand break. This DNA or oxidative damage can turn out to be hepatocellular carcinoma (HCC) or cancer [43–48].

Studies have demonstrated that HCC caused by AFB_1 is due to *p53* gene mutation which occurs as a result of transversion at 249 codon (guanine to thymine). This kind of mutation ends up with the arginine to serine substitution that causes 50% HCC due to AFB1 [45, 46]. The liver is the target organ for AFB_1 metabolism where mechanism of action starts with food ingestion. In the liver, cytochrome-P450 enzyme initiates metabolism of AFB_1 by transformation of AFB_1 to nucleophilic, reactive genotoxic intermediate (aflatoxin B_{1-8}, 9-oxide, AFBO) or hydroxylation and demethylation (as shown in **Figure 3**). When AFBO binds to liver cells, it results in DNA adduct formation, termed as 8, 9, dihydro 8, (N7-guanyl) 9-hydroxy-AFB_1. If this phenomenon extends after DNA replication, adduct reacts with *p53* tumor suppressor gene and causes mutation in it, resulting in HCC. Expression of mutated protein (R249Sp53) may lead to inhibition of apoptosis, inhibition of *p53*-mediated transcription, and liver cell growth [45].

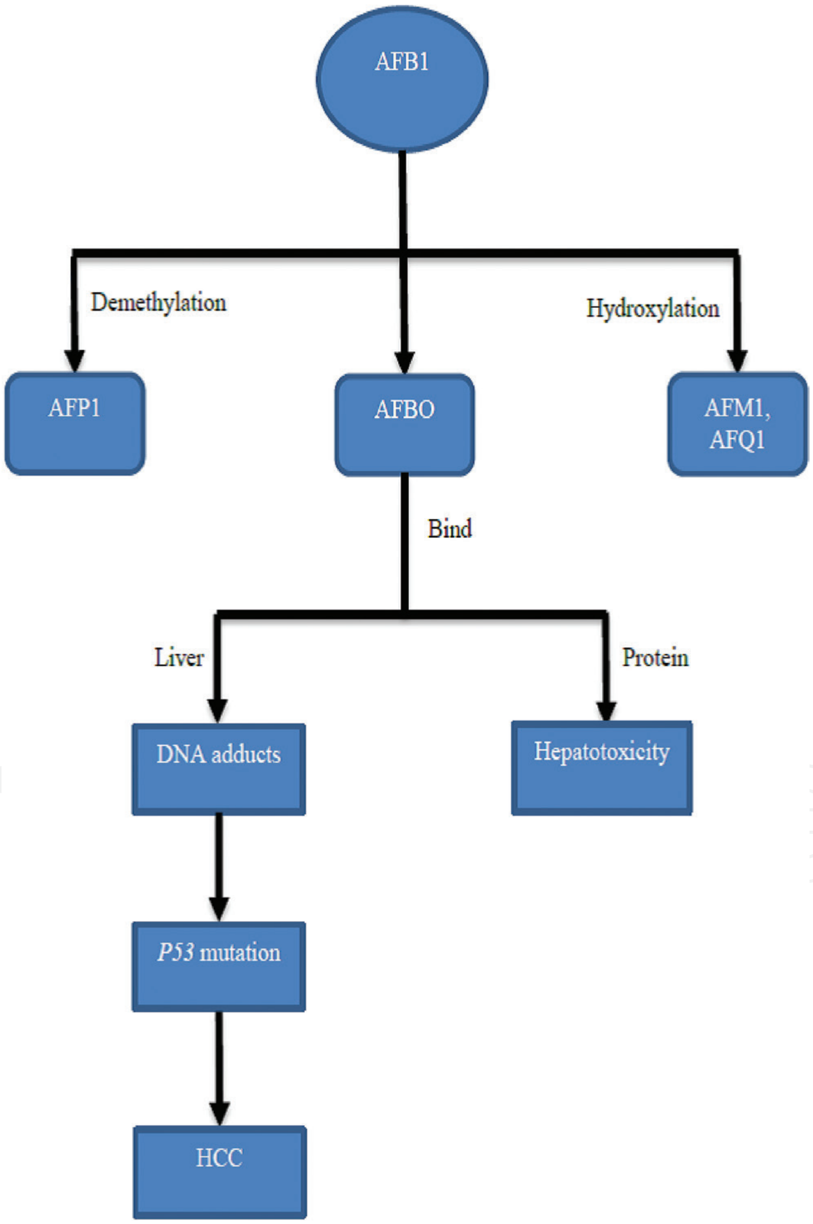

Figure 3. Biotransformation from AFB1 comprises CYP450-mediated reaction resulting in nucleophilic genotoxic reactive intermediate (AFBO), hydroxylation (to AFM_1 and AFQ_1), or demethylation (to AFP_1). AFBO binds to the liver cell and causes mutation in *p53* which leads to HCC. AFBO when binds to protein amino acids causes aflatoxicosis.

5.4. Immunosuppressive action of aflatoxins

Aflatoxins are major factor causing suppression in the immune system which further affects humoral and cellular response. Animal exposure to aflatoxin showed dose-dependent response in percentage of splenic $CD8^+$ T cells, $CD3^-$ $CD8a^+$ cells, natural killer (NK) cells [51, 55, 56]. Reduced expression level of cytokine mRNA in the intestine was observed in a study that might be due to reduced percentage of T cells in broiler. This phenomenon directly affects the immune function of intestinal mucosa [49].

6. Factors affecting the aflatoxin production in street-vended foods

Many fungal strains are genetically capable to produce mycotoxins, but they may not do so until certain conditions are met, and it is known that aflatoxin contents in food vary directly with the processing and storage methods and the associated producer microbe. Physical, chemical, and biological factors can affect the formation of aflatoxins in street-vended food including conditions such as temperature, moisture content, the location of vendors, the storage of utensils, personal hygiene, and method of reheating and storage of food. Availability of nutrients to enhance the fungal growth or energy sources such as sugar and vegetable oil will enhance the toxin production [26], for example, there was a higher aflatoxin produced by *A. flavus* on peanut and cottonseed than rice and sorghum; also, it was reported that some fungi like *Alternaria* and *Fusarium* can cause either preharvest or postharvest contamination of grains. In another study, *P. viridicatum* was reported to produce more stable citrinin and ochratoxin on grain compared to meat [50]. The most important climate factors favoring the aflatoxin production are temperature and moisture; optimum temperature for the growth of aflatoxins ranges from 25 to 37°C. *A. flavus* and *A. parasiticus* produced aflatoxin at 12–41°C, 14% moisture content, and humidity >62% followed by rapid drought [52, 53]; example is the 2004 drought-induced aflatoxicosis breakout in Kenya [49, 54].

The location and conditions set for preparing and storing street food may contribute to the production of fungal toxins. Jonathan et al. [31, 55, 56] reported variations in biodeteriorating fungi and aflatoxin contents of particular foodstuff collected from different locations in Nigeria. Most of the vendors are illiterate and do not have knowledge about the sanitary conditions [57]. A case reported in Africa showed that 85% of food stalls were located near garbage dumping sites [58]. Some storage molds such as *Aspergillus* and *penicillium* can survive environments with very low water content. In postharvest storage of food crops, aflatoxin production may be triggered by prolonged drought-associated elevated temperatures [58]. In some other cases, early harvest is also a good strategy to control mold contaminations [59]. Kaaya et al. [60] observed about 4 times increase in aflatoxin levels during the 3rd week and 7 times more in delay harvest after 4 weeks. However, following early harvest, crops have to be well dried to safe fungi contamination. Rachaputi et al. [61] observed least aflatoxin contents in early groundnut harvest and 27% increase in delayed harvest.

Many traditional ways used for food preparation such as heating and roasting can reduce the aflatoxin contents in foods; ranging values in sausage rolls prepared from different locations in

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Nigeria were observed by Jonathan et al. [55] due to different methods adopted for its preparation; Fandohan et al. [62] determined the fates of aflatoxin and fumonisin in different traditional ways of preparing maize and maize foods based on washing, sorting, winnowing, and hulling combined with crushing of the grains; this is also supported by Park [63] and Lopez-Garcia and Park [64]. The presence of other microorganisms either bacteria or fungi may alter elaboration of mycotoxins on food materials, for example, there was reduced aflatoxin production when *A. parasiticus* was grown in the presence of some bacteria, *Streptococcus lactis* and *Lactobacillus casei* [65]. Meanwhile, fungal metabolites such as rubratoxins from *Penicillium purpurogenum*, cerulenin from *Cephalosporium caeruleus*, and *Acrocylindrium oryzae* enhance aflatoxin production even though they repress growth of aflatoxin-producing fungi [66–69].

Aflatoxin-producing fungi can contaminate food crops during cultivation, harvest, transport, storage, or food preparation [70–72]. Iaha et al. [70] reported that insect damage of maize enhances *Fusarium* mycotoxin through the inoculation of fungal spores into the wounds made on the kernels or stalks during feeding [73]. Higher aflatoxin contents were recorded in maize samples stored in high moisture content up till 10 [74–76]. Most of the people involved in street food vending are lower or middle class people who have more concerns for income or quantity than the quality of their products; many of them lack quality information on how to maintain good hygiene. Most street hawkers always believe in improvised cheap usage of materials during the food processing which may contravene the quality of the food product. However, these food products are sold to many people including the high class group of people. The lack of mycotoxin awareness among the street food vendors is one of the factor increasing mycotoxin incidences in foodstuffs. Many contaminated foods are still sold to avert loss of investment; many of the infected foodstuffs are sold at cheaper amount, and people tend to still buy them especially in countries with high poverty level.

7. Economic impact of mycotoxins

Effect of aflatoxin on the economy require good imparts assessment model experts and data sets [80]; this may include income losses due to deaths of livestock, weight loss, reductions in productivity, and the yield of eggs, meat, and milk. It affects aves (poultry) such as ducks, chicken, and turkeys; mostly prime example is that of the 1960 outbreak of "Turkey-X disease" in the United Kingdom caused about 100,000 turkey deaths; it may also lead to loss in fishes, birds, rabbits, dogs, and other mammals. The effect of aflatoxin on economy, storage loss, and generally output loss in animal husbandry due to aflatoxin incidence would be threatened here. Aflatoxin lethal dose (LD-50) is generally between 0.5 and 10 mg/kg of livestock body weight; however, high dose of mycotoxin was responsible for, another case with more economic loss may still occur if mycotoxins are not controlled. There is a need for capacity building to enhance the analysis economic impact of mycotoxin and trade analysis.

Mycotoxin contaminations may also affect other sectors of food production and agriculture. Infected commodities can be rejected from shipments, and some prices may become reduced due to loss in quality; this can devastate export markets especially in developing countries. The consumers may be indirectly affected by increased price/costs of food materials as the sellers/producers levied extra cost due to maintenance against contamination or health risks if they are only able to afford contaminated products which are always cheaper. Farmers may suffer reduced income, feed loss, or low outputs due to aflatoxin/mycotoxin interference most especially on the stored products, and economy impact of mycotoxins stems from high mortality, immunity, weight loss, fertility, and quality of dairy products in livestock.

However, we need to checkmate the mycotoxin preventive cost over economic cost; preventive cost in most cases saves many products as the saying "prevention is better than cure" and yields better production and storage practices. Most African countries such as Gambia, Ghana, Mali, Niger, Nigeria, Senegal, as well as Sudan have reported about 7.5 million US$ cost for mycotoxin control programs due to high-reported mycotoxin incidences on foodstuffs like peanuts and many cereals. In addition, fungi biodeterioration of foodstuffs has caused many countries economic loss due to rejection of exported foodstuffs and affected relationships with trading partners. Implementation of credible food safety controls by exporting countries is needed to foster their smooth exportation of food and agricultural produce. Quality assurance by importing countries has to be routine, and by so doing, the manufactured food will have insignificant mycotoxin levels. The exporting country must be able to comply with this requirement and demonstrate that compliance has been realized. Effectiveness of control measures requires important elements such as administrative structures, resource management, scientific and technical infrastructure, and financing and human capital. Lack of efficient management of resources in many countries has been verified to compromise the credibility of food safety controls. In 2010, foods worth more than US$200,000 were destroyed by regulatory agencies in Nigeria as a result of contamination by mycotoxins.

Aflatoxin (B_1, B_2, G_1, and G_2) level in product (ng/g) can give a mark of quality and can be used as a threshold for distinguishing low-, medium-, and high-quality product. Africa could have accrued an estimate of 67 million dollars annually, but this is lost due to export rejection of its food and agricultural produce contaminated with high levels of mycotoxins. Over the years, the European Union Rapid Alert System has notified Nigeria on its alarming export rejects. Contamination by mycotoxins is owed to hot and humid conditions, soil condition, storage method, crop variety, cultural practices, harvesting procedures, etc.

8. Prevention of aflatoxin contamination in street-vended foods

Adequate practices such as pest and disease control management are needed for safe and healthy food production; this must be judiciously implemented to tackle the menace of aflatoxin spoilage of storage and dairy agricultural produce. Early harvest of agricultural produce may avert aflatoxin/mycotoxin contaminations as the fungi that produce these toxins are usually associated with deterioration of the organic compounds. More also, mycotoxin prevention starts right from the cultivation and rearing of livestock. The use of contaminant-free tools, sterile water for washing, and some other hygienic measures needs to be taken seriously either the products are to be consumed or for sale. Some scientists suggest harvesting at dry period, and storage of agricultural produce in dry environment as wet condition improves the growth of molds [77]. Proper cleaning of harvested products, removal of spoilt products (most especially grains), and proper storage methods are good for mycotoxin control. Good transport and storage mechanisms and frequent check for daily temperature and humidity are good for mycotoxin control.

Many scientists have suggested the use of living organisms to nullify or reduce mycotoxin contamination [78]; this is called *biological control measures*. In this method, the mycotoxin-producing fungi or the pest that can act as vector are targeted. The organisms that kill, feed, or attack the toxin production organisms or vector are introduced. In the United States, biological control measures for mycotoxin have been encouraged for various crops like cotton, peanuts, and maize. In Nigeria, the International Institute for Tropical Agriculture (IITA) has reported much success in biocontrol measures on aflatoxins reported as *Aflasave* measures; this has been tried on many crops [79].

Physical methods such as sorting out bad or infected products from healthy ones, hygienic handling, and maintenance of clean environment can reduce aflatoxin/mycotoxin incidence in street-vended foods or industrial food products [67]. A center control point for testing all street-vended food may be set up by the government to reduce mycotoxin incidence. Regulatory measure on mycotoxin should be strengthened in every country. Food management system point will save a lot from food poisoning [80]. Conduction of test at different steps in food production is also important in big food industries; this may be coupled with the use of supplier's schemes. Hazard and analysis critical control point (HACCP) for pre- and postharvest stage plan has save many commodities from contaminants; this has been used on coconuts and corn in South East Asia and on nuts in South and West Africa; it has also been used on apple juice and pistachio nut in South America [79]. Detailed information on HACCP was reported by FAO [79] and suggested the implementation of HACCP for adequate fungal toxin management.

9. Regulations on fungal toxin (mycotoxin)

Legislation and food inspections are very important for food security. For thousands of years back, food has always been subjected to legislation and inspection as the need was felt for some control on the quality of food materials. This control was intended to safeguard the health of consumers and as well prevent cheating in terms of the composition of food; the principle that food contaminated with a hazardous substance is unfit for human consumption and shall not be sold or offered for sale was not always applied as intended. Before, local and municipal affair/ordinances were used for regulated food quality as there were no advanced scientific methods and tools, but today, advances in science of bacteriology, microscopy, and chemistry have aided official legislations on food. Today, we have legislations that prohibit adulterated or misbranded foodstuffs and incidence of contaminants in food particularly incidence of these contaminants above the tolerance limit in either humans or animals.

Mycotoxins as a food toxic substance have recently been considered in food regulation (**Table 5**). It started shortly after the aflatoxin discovery in the 1960s, and some other specific mycotoxins such as ochratoxin, zearalenone, deoxynivalenol, patulin, and phomopsin were later considered. An attempt to study the whole world's legislation on mycotoxins was made by the International Union of Pure and Applied Chemistry (IUPAC) and the Food and Agriculture Organization which led to an updated paper that was published by Schuller et al. [80] in the

Country	Food material	Tolerance level (μg/kg)		Authority
		B1	**B2 + G1 + G2**	
Argentine	Sugar-coated nuts	–	5	Ministry of Public Health, Ministry of Agriculture
	Peanuts, peanut products, maize products	5	20	Ministry of Public Health, Ministry of Agriculture
	Infant foods based on cereals and AH foods	2		Ministry of Public Health, Ministry of Agriculture
Australia	All foods except peanut products	3	–	National Health and Medical Research Council, 1982 (recommendation)
Australia	Peanut (products), all foods, except milling and shelled products	15 1	5	Not official Ministry of Public Health
	Milling and shelled products and derived products children foods	2 0.02	5 0.02	Ministry of Public Health Ministry of Public Health
Belgium	All foods	5		Ministry of Public Health and Ministry of Agriculture (not official)
Brazil	Industrially prepared foodstuffs for children from 0 to 2 years and for school meals Imported foodstuffs	5	3 10	Proposed
	Other foodstuffs	15	30	Proposed
Canada	Nuts and nut products		15	Health and Welfare Canada (official)
China	Rice, peanuts, maize, sorghum, beans, wheat barley, oats	50		Ministry of Public Health, Council of Agriculture and Local Authorities (official)
Colombia	Sesame seed		20	Publication official del Instituto Colombiana de normas technicas "Icontec." Norma Colombiana nr. 536, edicion 1981
	Oil seeds (peanuts)		10	Ministry of Public Health (official)
	Cereals, grains (sorghum, millet)		30	Ministry of Public Health (official)
Cuba	Cereals, grains, peanuts		0	Ministry of Agriculture
Czechoslovakia	Cereals, grains, peanuts All foods except infant and children foods	5	10	Ministry of Health (official)
	Infant foods on milk basis (calculated on basis of reconstituted product) Other infant foods and children foods	0.1 1	0.2 2	Ministry of Health (official)
Denmark	Peanuts		10	Ministry of the Environment (official)

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Country	Food material	Tolerance level (μg/kg)		Authority
		B1	B2 + G1 + G2	
Dominican Republic	Maize and maize products, peanuts, soya, tomatoes, and products thereof		0	Ministry of Agriculture and Ministry of Public Health
Finland	All foods		5	Decision of the Ministry of Trade and Industry on some food contaminants (762), 1984, Ministry of Trade and Industry; National Board of Trade and Consumer Interests
France	All foods Infant foods Dietary milk Foods		10 5 O-1l^g/100 kilocalories (=0–024 ^g/100 kj)	Conseil Supérieur d'Hygiène Publique de France, séance 25.10.1975 Interests, Ministry of Consumption Arrêté 5.01.1981 Journal Officiel de la Republique Française; 11.01.1981, Ministry of Consumption Arrêté 30.03.1978 Journal Officiel de la Republique Française; 11.01.1981, Ministry of Consumption
Federal Republic Of Germany	Peanuts, peanut products, hazelnuts, walnuts, brazil nuts, pistachio nuts, apricot and peach pits, poppy and sesame seeds, cereals, cereal products, grated coconut, almonds	5	10	Aflatoxinverordnung Bundesgesundheitsblatt IS 3313 of 30.11.1976, Various Not ministries, official depending on the State
German Democratic Republic	All foods	5	10	Circular of Ministry of Health 1970, Ministry of Health
Hong Kong	Infant foods and children foods. Peanuts and peanut products		20	Municipal Services Branch, Goment Secretariat, Hong Kong Government Ministry of Ministry Health of Ordinance Health No. 4 of 25.06.1978
Hungary	All foods	5		Ministry of Health of Ordinance Health No. 4 of 25.06.1978
India	All foods Israel Ireland Italy Grains and nuts, peanuts	30		Ministry of Health and Family Welfare, Department of Health Ministry of Health (official)
Israel	Grains and nuts		20	Ministry of Public Health
Ireland	All foods	5	30	
Italy	Peanuts		50	Ministry of Public Health
Japan	All foods	10		Food Sanitation Investigation Council, April 1974, Ministry of Health and Welfare (official)
Jordan	Almonds, cereals, maize, peanuts, pistachio nuts, pine nuts, rice	15	30	Minister of Finance and Customs Instructions (5/35/8251) 11.03.1981; letter of Minister of Health (48/37/2049) 03.03.1981, Ministry of Health

Country	Food material	Tolerance level (μg/kg)		Authority
		B1	B2 + G1 + G2	
Kenya	Peanuts and other vegetable oils, peanut products		20	Food, Drugs, and Chemical Substances Regulations Kenya Gazette, 01.07.1978, Ministry of Health
Luxembourg	Peanuts and peanut products	5		Règlement Grand-Ducal of 22.09.1978 Loi 25.09.1953, art.7f.ll and 12 Benelux Arrêté M(77) 5-03.05.1977 Ministry of Public Health
Malawi	Peanuts (export)	5		Letter of Malawi Bureau of Standards BS/1/1 of 24.06.1976
Malaysia	All foods		35	Food Regulations 1985
Mauritius	Groundnuts Others	5 5	15 10	Food and Drug (Control of Aflatoxins) Regulations, 1979. Government 1: Notice No. 222 of 19.9.1979
Mexico	All foods		20	Ministry of Official Public Health, Ministry of Agriculture
The Netherlands	Peanuts and peanut products All foods and food ingredient	5 5		Algemeen Besluit (Warenwet) art.3 quinquies. Staatsblad van het Koninkrijk der Nederlanden 46, artikel 1, 19.01.1974, Ministry of Welfare, Public Health and Cultural Affairs Ministry of Welfare, Public Health and Cultural Affairs Official
New Zealand	Peanut butter, shelled nuts and nut portion of products containing nuts, other foods		15	Food Regulations 1984, section 257
Nigeria	All foods Infant foods	20 0		Food and Drug Administration (official) Food and Drug Administration (official)
Norway	Nuts, buck wheat, other foodstuffs	5		Rundskriv IK-1/85 of 08.02.1985
Peru	Maize and peanuts	5		Code of practice
Philippines	Coconut, peanut products (export)	20		Ministry of Health
Poland	All foods	0		Ministry of Public Health
Portugal	Peanuts Infant foods Other foods	25 5 20		Decreto-Lei no.6/83 nr. Diàrio da Républica of 14.01.1983, Ministry of Public Health, Ministry of Agriculture, Ministry of Commerce (official)
Romania	All foods	0		Joint papers of veterinary specialists and doctors of medicine 1978, Ministry of Health Ministry of Agriculture

Country	Food material	Tolerance level (μg/kg)		Authority
		B1	**B2 + G1 + G2**	
Singapore	All foods	0	0	Food Regulations 1974, art. 2, para 3c Government Gazette no. 4959-16.01.1976 Ministry of the Environment
South Africa	All foods	5	10	Government Gazette no. 4959-16.01.1976
Surinam	Peanuts, peanut products, pulses	5		Gouvernementsblad van Suriname nr. 199, 1971, Food Inspection Service (not official)
Sweden	All foods		5	National Food Administration's Ordinance (SLV FS 1983: 1) on Foreign Substances in Food, SLV FS 1985: 16, Swedish National Food Administration
Switzerland (existing regulations) Proposed regulations	Almonds, peanuts, hazelnuts, walnuts, brazil nuts, pistachio, apricot and peach kernels, grated coconut, poppy, sesame, peanut butter, peanut flips, arachis oil (not refined, bottled), pumpkin, kernels, maize, cereals All foods, except maize and cereals	1 2 1	5 5 5	Verordnung über die hygienisch-mikrobiologischen Cantons Anforderungen an Lebensmittel, Gebrauchs-und Verbrauchsgegenstände 817.024 of 14.09.1981
Thailand	All foods		20	Ministry of Public Health Notification no. 98.B.E. 2529: Standard for Food Containing Contaminants, Ministry of Public Health (official)
Union of Socialist Soviet Republics	All foods	5		Methodic Documents Minszdrav USSR 2273-80 of 10.12. 1980 and 4082-86 of 20.03.1986, Ministry of Health and State Agric Industrial Committee of the USSR
The United Kingdom	Nuts and nut products	10		Proposal, MAFF press release 181 of 08.07.1986, Ministry of Agriculture, Fisheries and Food
Yugoslavia	Wheat, maize, rice and other cereals, beans	5	1	Article 57, Federal Register no. 2, 1980, Slüzbeni list Socijalisticka Federation Republika Jugoslavija 2/1980, Federal Committee for Labour, Health and Social Welfare (official) Article 57, Federal Register no. 2, 1980, Slüzbeni list Socijalisticka Federation Republika Jugoslavija 2/1980, Federal Committee for Labour, Health and Social Welfare (official)
Zimbabwe	Groundnuts, maize, sorghum	5	4	Ministry of Agriculture

Table 5. Legal aflatoxin tolerance levels in foodstuffs for humans [80].

1987 (second) mycotoxin joint International annual Conference of FAO/WHO/UNEP. The mycotoxin legislation has since then grow exponentially in various countries. Many countries are known to enforce or propose certain aflatoxin regulations for foodstuffs to continue to increase, and many countries expanded their regulations to specify more types of foodstuffs. As in 1981, the maximum limits for aflatoxins in food (aflatoxin B1 or the sum of aflatoxins B1, B2, G1, and G2) vary from zero detectable to 50 jtg/kg. The strategies which may be employed to limit the establishment of mycotoxins in food should include both on-field and post-field measures. The regulation of a country is to ensure that any food contaminated in an amount that is intolerable from a public health point of view, particularly, at a toxicological level, is not tradable in that country. Contaminant levels are required to be kept as low as possible by proper measures. Regulations are established in many countries to control food contamination so as to protect human health; these regulations may include specific maximum limits for several contaminants for different foods and a reference to the sampling methods and methods of analysis used [81, 82]. Report by FAO in 2003 shows that about 100 countries have existing regulations on mycotoxins in specific foods and feeds; this was about 30% increase over 1995 report.

However, studies have shown that most African countries have adequate mycotoxin regulations due to the fact that many countries in Africa account for highest countries with massive aflatoxin incidence. Morocco had the most detailed regulations on mycotoxins with about 15 nations out of about 99 countries with known mycotoxin regulations in 1995. Nigeria, for example, adopted its regulatory system from the European commission used primarily on export commodities. However, mycotoxin regulatory status quo in African countries still needs to be improved upon especially for effective implementation.

10. Conclusion

In this chapter, it would be understood how historical events should gear enforcement of regulatory limits for foods produced locally in order to maintain a high standard especially in foreign trading. This chapter elucidated the need to devise principal methods of mycotoxin control in food and human. It would be understood that mycotoxins in food commodities are a result of fungi infection. It would reiterate the need for proper cultural practice, sanitation, and good storage procedures, among others, as possible measures.

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