Chapter

Aflatoxins: Food Safety, Human Health Hazards and Their Prevention

Enespa and Prem Chandra

Abstract

Aflatoxins (AFTs) are group of secondary metabolites produced by filamentous fungi such as *Aspergillus flavus, A. parasiticus, A. nomius*, and *Emericella nidulans*. AFTs contaminate foods, feeds, other raw ingredients used to produce them and that pose a significant threat to human health. These toxins designated as aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1), and aflatoxin G2 (AFG2), aflatoxin M1 (AFM1) and aflatoxin M2 (AFM2) are hydroxylated metabolites form of AFB1 and AFB2 are known as difuranocoumarin compounds. Naturally, these AFs have carcinogenic, teratogenic and mutagenic effects and caused several metabolic disorders such as aflatoxicosis in domestic animals and humans worldwide. For the increasing in cancer incidences these risk factors are liable. AFB1 is 1000 times more potent hepatocarcinogen found in food then benzo (α) pyrene carcinogen. This chapter offers contamination sources, effects and their controlling approaches to confirm the food safety.

Keywords: Aflatoxin, health, risk assessment, aflatoxicosis, teratogen, carcinogen, mutation, hepatocellular carcinoma

1. Introduction

The fungi *Aspergillus flavus, Aspergillus parasiticus*, *Aspergillus nomius* and *Aspergillus tamari* produced aflatoxins are naturally secondary metabolites bisfuranocoumarin compounds [1, 2]. In agriculture *A. flavus* is a mutual contaminant and *A. pseudotamari A. bombycis*, *A. ochraceus*, and *A. nomius* are normally aflatoxin-producing species. *A. minisclerotigenes* and *A. arachidicola* are two another newly defined aflatoxigenic species [3]. Aflatoxins - B1, B2, G1 and G2 are four common contaminants of food products. Aflatoxins biosynthetically arise through polyhydroxy anthraquinone intermediates are acetate-derived decaketides. *A. flavus* and *A. parasiticus* species are found universally in the soil and air and grow at temperatures between 22 and 35°C [4, 5]. Aflatoxins classified as teratogenic, genotoxic, carcinogenic and invisible poisons by the World Health Organization (WHO). The multiple staple foods, cash crops such as maize, tree nuts, cassava, millet, peanuts, wheat and a range of spices contaminated by aflatoxins. In the milk, eggs, and meat from animals fed contaminated feed. Aflatoxins have been also detected in eggs, milk, and

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meet using contaminated feed [6, 7]. The drought and pests attacks endangered to stress factors of crops when preharvest occurrence of aflatoxin increases. With poor drying, storage and handling contamination spikes after post harvesting. Aflatoxins symbolize an excessive health and socio-economic issues for both industrialized and underdeveloped countries [8, 9]. At any stage of food production contamination can occur from pre-harvest to storage. It can be carcinogenic, hepatotoxic, teratogenic, and mutagenic at very small concentrations to human health by ingestion, inhaled, or absorbed through the skin [10, 11]. In several countries aflatoxins causes aflatoxicosis. In 1960, the aflatoxin causes Turkey X disease which is known as hepatic necrosis. High levels of aflatoxin and chronic hepatitis B virus (HBV) infection both exposed individually which increased liver cancer risk greatly in several parts of the world in Asia and sub-Saharan Africa [12, 13]. Aflatoxins and other toxins are analyzed in agricultural products by the Food and Agricultural Organization (FAO) and WHO. These toxins cannot be destroyed after contaminations of foods by the usual cooking processes. Furthermore, these toxins partially or completely eliminated from food using by physical, chemical and biological methods can be applied and assurance the food safety and health concerns of users [14, 15]. Hazard analysis of critical control points (HACCP) and good manufacturing practices are the recent advances have been developed keep final food products safe and healthy. An overview of aflatoxigenic fungi, their health hazards to humans and livestock, the biosynthesis of aflatoxins and their chemistry, along with their variety in existence are discussed in this chapter.

2. Source of aflatoxins

A number of airborne conidia and propagules that infect plants like cotton created by *A. flavus* [16]. During harvest in the agriculture form, in storage conditions, and during processing grains can be infected by *A. flavus*, *A. parasiticus* and are commonly isolated from corn, cottonseed, peanuts, and tree nuts (**Figure 1**).

Aspergillus flavus can grow at temperatures ranging between 12 and 48°C and consisted of mycelium, conidia, or sclerotia [17]. AFB1, AFB2 produces by *A. flavus* but AFG1, and AFG2, AFB1, and AFB2 are produces by *A. parasiticus* and *A. nomius* fungal isolates [18]. The hydroxylated metabolites which is known as AFM1 and AFM2 produced by AFB1 and AFB2 (**Figure 2**). AFB2 and AFG2 are manufactured

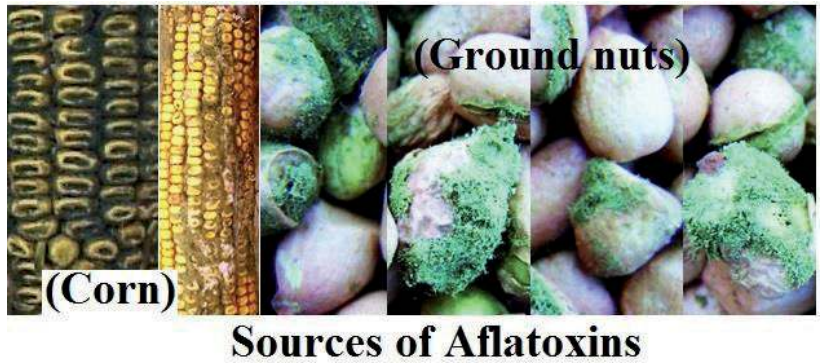


Figure 1.
Source of aflatoxins in depicted in ground nuts and corn.

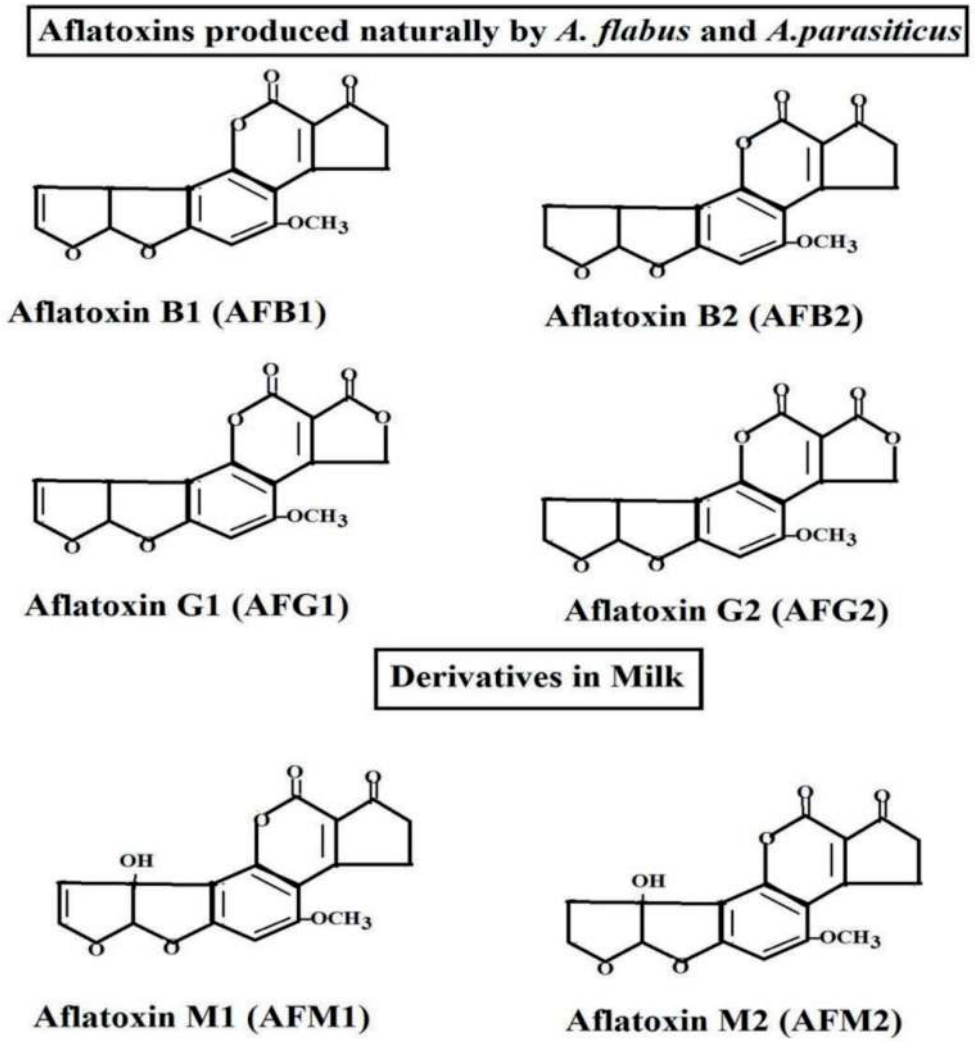


Figure 2.
Aflatoxin produced by A. flabus *and* A. parasiticus *showing chemical structure.*

at one-tenth to one-third of the amount of AFB1 and AFG1, correspondingly. And in largest quantities of AFB1 is produced in several strains [19, 20].

After classification by the International Agency for Research on Cancer (IARC) in 1987 (Category 1A) the aflatoxin B1 is as carcinogen, and AFM1 is a potentially carcinogenic substance with a toxicity range of AFB1 > AFG1 > AFB2 > AFG2 according to Category 2B. Aflatoxin detected in food in majority that ultimately harms to human and animal health among the mycotoxins affecting food and feed [21, 22]. Under the culture conditions most of the species produced major mycotoxin known as aflatoxin B1. AFB1 and AFB2 are named because of their strong blue fluorescence under UV light, whereas AFG1 and AFG2 fluoresces greenish yellow [23]. The B-toxins are categorized by the fusion of a cyclopentenone ring to the lactone ring of the coumarin structure, while G-toxins contained and additional fused lactone ring. In human other metabolites of AFB1 include Aflatoxin Q1 (AFQ1), aflatoxicol (AFL), AFM1, AFB2 and AFB1–2, 2-dihydrodiol. Both un-metabolized (B1, B2, G1, G2) as well as metabolized forms (aflatoxicol, M1 and M2) of aflatoxins get excreted in urine, stool and milk [24, 25].

3. Gene for aflatoxin production

Several genes and their enzymes are involved for the production of sterigmatocystin (ST) dihydrosterigmatocystin (DHST) (**Figure 3**) known as aflatoxins precursors [26, 27]. During the biosynthesis of aflatoxin gene nor-1 was first cloned in *A. parasiticus* named after the product formed by the gene. According to substrate product formed these genes entitled as Nor-1 (norsolorinic acid [NOR]), norA, norB, avnA (averanti [AVN]), avfA (averufin [AVF]), ver-1 (versicolorin A [VERA]), verA and verB while those based on enzyme functions fas-2 (FAS alpha subunit), fas-1 (FAS beta subunit), pksA (PKS), adhA (alcohol dehydrogenase), estA (esterase), vbs (VERB synthase), dmtA (mt-I; O-methyltransferase I), omtA (O-methyltransferase A), ordA (oxidoreductase A), cypA (cytochrome P450 monooxygenase), cypX (cytochrome P450 monooxygenase), and moxY (monooxygenase) [28, 29]. In *A. flavus* [30] primarily the aflatoxin regulatory gene was named afl-2 and in *A. parasiticus* named apa-2 [31]. But in *A. flavus, A. parasiticus*, and *A. nidulans* it is symbolized as aflR due to its part as a transcriptional activator. AflA (fas-2), aflB (fas-1), and aflC (pksA) accountable for conversion of acetate to NOR reported in earlier observations [32, 33]. Furthermore, in *A. parasiticus* for NOR biosynthesis as well as aflatoxin production the uvm8 gene was reported to be essential. From *Saccharomyces cerevisiae* the amino acid of sequence gene is related to the beta subunit of FASs (FAS1) [34]. During aflatoxin synthesis FAS forms the polyketide backbone and

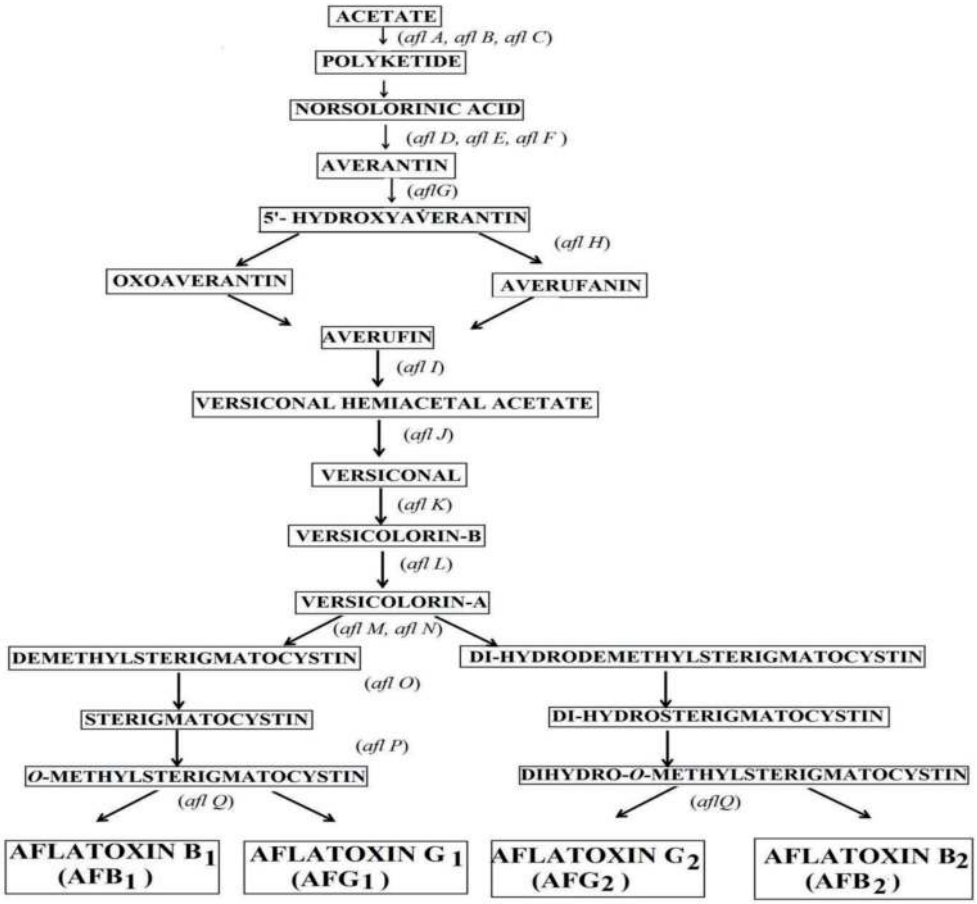


Figure 3.
Pathway of AFB1, AFB2, AFG1, and AFG2 production.

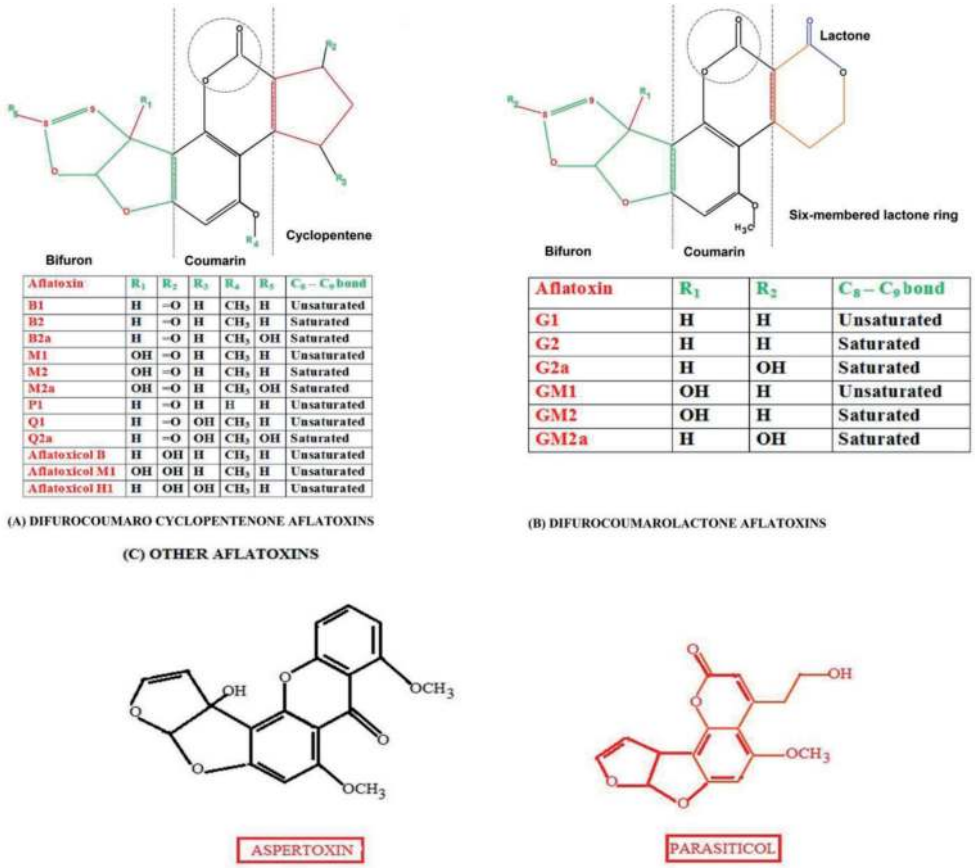
uvm8 gene known as fas-1 [35]. In *A. nidulans* the fatty acid syntheses (FASs) is responsible for sterigmatocystin (ST) biosynthesis and recognized as stcJ and stcK gene which encoded as FAS-2 and FAS-1 subunits [36].

4. Aflatoxin biosynthesis and regulation

The aflatoxin biosynthesis is very sophisticated [37], *A. flavus* and *A. parasiticus*, are extremely homologous and the genes of AF biosynthesis generally known as AF producers. The order of 25 genes within the aflatoxin gene clusters in two organisms has been displayed to be same [38]. Approximately 23 enzymatic reactions steps are involved in the AF biosynthetic pathway and recent investigations have revealed that about 30 clustered genes in AF biosynthesis mechanism. In *A. flavus* the pathway for AF biosynthesis are encoded by the 75 kb gene cluster for the gene encoding [39]. Within the gene cluster 29 AF biosynthetic genes have been identified [40] and exposed their functions. At least 21 enzymatic reactions consisted in the entire AF biosynthetic pathway. In the genome of *A. flavus* and *A. parasiticus* the AF pathway genes clustered in one locus expressed simultaneously [41]. The AF structural genes are the complex process in the expression and controlled by the acting regulatory genes are aflR located of the AF gene cluster in the middle. Adjacent to aflR gene aflS was found to be relating with aflR and sharing in the transcription regulation [42]. Another gene involved in regulation of the aflatoxin gene expression non-coded by the aflatoxin gene cluster. LaeA and VeA positively regulate aflatoxin production known as global regulators. In *A. flavus* and *A. parasiticus* strains deletion of VeA caused disruption in aflatoxin manufacturing [43, 44]. In *A. flavus* hundreds of genes are regulated by VeA such as secondary metabolite and developmental gene clusters also influenced by presence or absence of light [45, 46]. To form protein complex designated velvet, putative methyltransferase LaeA and the velvet protein VeA to interact with each other have been shown. For the synthesis of AF, cyclopiazonic acid and aflatrem require to regulate the expression of several crucial genes interacts with velvet domain containing proteins and global regulator VeA [47, 48]. In DNA methyltransferase the dmtA mutants deficient revealed diminished asexual reproduction and aflatoxin biosynthesis. The dmtA mutants scarce in DNA methyltransferase exhibited reduced asexual reproduction. In contrast with wild-type strain *A. flavus* and aflatoxin biosynthesis signifying the dmtA hit valuable in the aflatoxin cluster of transcriptional level of genes [49, 50]. Furthermore, in the seed infection dmtA deletion induced such changes, resulted more conidia formation in crop seeds comparison to wild type strain. By the transcription factor NsdC the asexual growth and AF manufacture were regulated. In *A. flavus,* transcription factor is a key controller in aflatoxin metabolism and conidia formation both, transcriptional regulator nsdC have elevated its role [51, 52].

5. Aflatoxins and their structural diversity

The polyketide pathway synthesized difuranocournarins/difurocoumarins and known as aflatoxins structurally and consist of a coumarin nucleus (**Figure 4A** and **B,** black in middle) to attached a difuran moiety in one side (**Figure 4A**, left in green) and a pentene ring (**Figure 4A**, in red on right side) or a hexane lactone ring in the other side (**Figure 4B**, red on the right side) [53]. They fall in to two main groups on this basis aflatoxins: (i) difurocoumarocyclopentenones contained usually aflatoxin B series and their byproducts (**Figure 4A**), and (ii) difurocoumarolactones with aflatoxin G series as the main agents, counting AFG1, AFG2, AFGM1, AFGM2, and AFG2a



Aflatoxin	R_1	R_2	R_3	R_4	R_5	C_8-C_9 bond
B1	H	=O	H	CH_3	H	Unsaturated
B2	H	=O	H	CH_3	H	Saturated
B2a	H	=O	H	CH_3	OH	Saturated
M1	OH	=O	H	CH_3	H	Unsaturated
M2	OH	=O	H	CH_3	H	Saturated
M2a	OH	=O	H	CH_3	OH	Saturated
P1	H	=O	H	H	H	Unsaturated
Q1	H	=O	OH	CH_3	H	Unsaturated
Q2a	H	=O	OH	CH_3	OH	Saturated
Aflatoxicol B	H	OH	H	CH_3	H	Unsaturated
Aflatoxicol M1	OH	OH	H	CH_3	H	Unsaturated
Aflatoxicol H1	H	OH	OH	CH_3	H	Unsaturated

Aflatoxin	R_1	R_2	C_8-C_9 bond
G1	H	H	Unsaturated
G2	H	H	Saturated
G2a	H	OH	Saturated
GM1	OH	H	Unsaturated
GM2	OH	H	Saturated
GM2a	H	OH	Saturated

Figure 4.
Aflatoxins chemical structures (A) Difurocoumarocyclopentenone (B) Difurocoumarolactone (C) Aspertoxin, a difuranoxanthane, and parasiticol, lacking the lactone ring of its parent aflatoxin G1, are occasionally considered as standalone mycotoxins.

(**Figure 4B**). Parasiticol usually known as aflatoxin B_3 considered as a member of the latter group despite the lack of the characteristic six-membered lactone ring (**Figure 4C**, right).

6. Conditions for manufacturing of aflatoxin B1

Aflatoxins are usually associated with drought stress often occurs in various crop in the agriculture field before harvest. During the rainy seasons the poor storage conditions can increase the aflatoxins concentration. And these conditions developed chiefly in humid and hot regions where humidity and high temperature are optimal for growth of molds and for production toxin [54]. Several factors provide an ideal environment which promotes the growth of fungi. The principal climatic circumstances such as erratic rainfall, drought, more temperature between 20 and 35°C and more humidity (40–89%), provides a suitable environment for the molds growth and aflatoxins production. In proper dried and stored foods the molds cannot grow properly [55].

7. Permitted levels of aflatoxin

Food and Drug Administration (FDA) permitted an entire quantity of 0.5 g/kg or 50 ng/l in milk and 20 ng/g in livestock feed in US. The permitted

levels of aflatoxin M1 in milk, milk products and baby food are 0.005 mg/kg in European countries. Various regulations for permitted levels of aflatoxin in livestock feed sets by other countries [56, 57]. For example the permitted levels of aflatoxin from 0.05 to 0.5 μg/kg setup by European Union (EU). The environmental factors like weather conditions are effective the determining acceptable levels of aflatoxin. In tropical countries the permitted levels of this toxin are more compared to cold countries [58, 59].

8. Biochemical mechanisms of aflatoxin carcinogenesis

8.1 Biotransformation of aflatoxins

Aflatoxins biotransformation is interconnected closely with their toxic and carcinogenic effects. Therefore, in species sensitivities to aflatoxin B1 (AFB1) - induced carcinogenesis the biotransformation pathways of aflatoxin are hazardous [60]. To the reactive AFB1–8, 9-epoxide requires microsomal oxidation of AFB1 to utilize its hepatocarcinogenic effects. AFBO serves as a critical pathway for AFB1 detoxification may be conjugated enzymatically with GSH (**Figure 5**). To form the primary AFB1-DNA adduct, 8, 9-dihydro-8- (N7-guanyl)-9-hydroxyaflatoxin B1 (AFB1-N7-Gua) when the epoxide reacts with DNA. And it can break down into the apurinic (AP) site or the AFB1-formamidopyrimidine (FAPY) adduct are the two secondary lesions. AFB1-N7-Gua adducts causes G to T mutations has been observed in *Escherichia coli* [61]. In blocked replication AFB1-FABY also resulted. In single-stranded DNA blocks replication the dominant species whereas the AFB1-FABY form present normally in double-stranded DNA is mutagenic [62].

8.2 Aflatoxins and their health consequences

The aflatoxin is an international food safety concern documented by WHO. Being the population with rural survival in developing countries aflatoxin exposure caused natural and environmental hazards and is most at risk and due to global food safety concern. The liver organ targeted specifically using aflatoxin [63]. Aflatoxins comprise fever, malaise, abdominal pain; vomiting, hepatitis and anorexia are early symptoms of hepatotoxicity of liver. Acute poisoning is rare and exceptional but the immunosuppressive and carcinogenic effects caused due to chronic toxicity by aflatoxins [64].

8.3 Aflatoxins related diseases

After consumption of mold damaged corn exposed to 2–6 mg of aflatoxin daily for approximately one month and caused aflatoxicosis characterized portal hypertension, jaundice, ascites and other signs of hepatic failure has been determined in humans. Liver cancer, kwashiorkor, Reye's syndrome including hepatotoxicity has been connected with nutritional contamination with aflatoxins caused adverse human health effects [65, 66].

8.4 Aflatoxicosis

Aflatoxins caused human intoxication via contact, ingestion and inhalation which affects the internal organs of the body such as salivary glands, colon, liver, kidney, stomach and lungs and skin. The gastrointestinal tract rapidly absorbs aflatoxin B1 after ingestion and metabolized in the liver [67]. Aflatoxins irreversibly

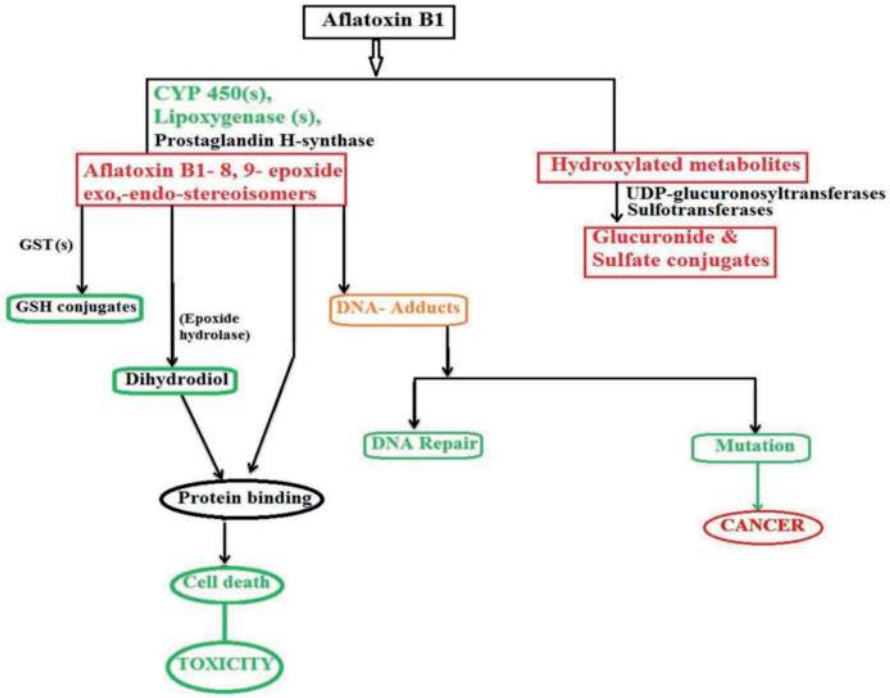


Figure 5.
Overview of bio-transformational pathways for aflatoxin B1.

bind to proteins and DNA bases after ingestion 1–3% and form aflatoxin B1-lysine in albumin. Protein and DNA bases disruption in hepatocytes causes liver toxicity. In a long period of time very small doses of aflatoxins ingestion caused chronic exposure. And acute aflatoxicosis determined after higher doses of aflatoxins. B1 > G1 > B2 > G2 is the order of potency for acute and chronic toxicity. AFB1 is not toxic itself, but it produces metabolites are more toxic, and its successive metabolism governs acute and chronic both toxicity [68, 69].

9. Gastrointestinal cancer and other cancers

In association with other mycotoxins AFB1 effects on Caco-2 cells were evaluated alone. Owing a cytotoxic effect at the concentration of 19.28 M, AFB1 resulted the third more cytotoxic among tested mycotoxin. To verify its effect on genotoxicity and DNA damage HCT116 colorectal cancer cells were treated with AFB1 (3–5 M) in another study [70].

9.1 Liver cancer

The improved risk of liver cancer is interrelated to AFB1 exposure revealed in earlier report. AFB1 is resulted to be an important hepatocarcinogenic. AFB1 induces the formation of DNA adducts that contribute to liver cancer formation indicated in 2002 to belong to Group 1 of the carcinogens [21]. With 4.6–28.2% of hepatocellular carcinoma (HCC) cases globally attributed to AFB1 exposure, Likewise, in AFB1-exposed people Hepatitis B virus (HBV) can increase the risk of HCC by 30-fold. Acute hepatitis caused by high exposure concentrations and as a result the chronic exposure causes the increase of liver cancer [71].

10. Possible mechanisms for the interaction between aflatoxin B1 and hepatitis B virus

To the carcinogenic effects of AFB1 the Hepatitis B virus infection may directly or indirectly sensitize hepatocytes. To bind to DNA causing changes AFB1–8, 9- epoxide has been displayed that increase the threat of assimilation of viral DNA and hence malignant transformation [72]. With heavy exposure to AFB1 the 249ser mutation is made-up to be a primary and early genetic event in hepatocarcinogenesis this mutation is present in 36.3 to 66% of patients. In sequences of the virus the HBV x gene is frequently included that are incorporated into the cellular DNA [73]. For removing AFB1-DNA adducts nuclear excision repair is accountable normally and is introverted by HBV x protein, approving the determination of present mutations or impaired DNA. To uncontrolled cell proliferation it may also contribute [74].

The p21waf1/cip1 transcription is initiated by HBVx protein in a dose-dependent method in the presence of functional p53 which induces cell cycle arrest, though the transcription is inhibited by HBV x protein when p53 is absent or present at a low level [75]. In transgenic mice in the total frequency of DNA mutations in transgenic mice the expression of HBVx protein also correlates and a 2-fold growth in the incidence of the 249 ser mutation exposed to AFB1. For an interaction between AFB1 and HBV another possible mechanism is that improved hepatocyte necrosis and propagation resultant from HBV infection increase the possibility of AFB1 mutations, comprising 249ser, and the successive clonal development of cells covers these mutations [76]. Generation of oxygen and nitrogen reactive species is the results of chronic inflammatory hepatic disease from HBV infection. Latter both are mutagenic, increased oxidative stress shown to induce 249ser mutations. In hepatocarcinogenesis altered methylation of genes may play an important role. Between ras association domain gene 1A (RASSF1A) methylation status and the level of AFB1-DNA adducts in HCC tissues a statistically significant association exists [62].

10.1 Potential mechanisms

Through liver toxicity the aflatoxin exposure may interrupt the pathway of insulin-like growth factors (IGF). Lower IGF1 levels described about 16% effect of aflatoxin on child height displayed in a path analysis. In another prospective device include the immunosuppressive effect of aflatoxin exposure for the aflatoxin child growth weakening that may upturn the susceptibility of infection, subsequently ruining the nutrition grade through appetite reduction and decrease the nutrient absorption [77]. Moreover, it is proposed that exposure to aflatoxin may stimulate the intestinal damage due to inhibition of protein synthesis. Consequently, the absorption of essential nutrients reduced and later impaired the growth. If the affiliation among impaired child growth and aflatoxin exposure is in fact causal it is challenging to establish on bases of above given evidence [78, 79].

10.2 Impaired child growth

During pregnancy dietary intake plays a necessary role in the child's future health status. Malnutrition and child growth impairment are major public health burdens in sub-Saharan Africa. At different time points the impact of aflatoxin on growth impairment has been investigated [80].

10.3 In utero exposure

Aflatoxin exposure can occur in utero through a trans-placental pathway have demonstrated in several observations. Lower birth weights and stunted child growth have been associated with higher exposure levels of aflatoxins in utero. The consequences of in utero exposure to aflatoxin analyzed on the white blood cell DNA global methylation level in children aged 2–8 months [81].

10.4 Exposure via breast milk

Breast milk is the potential source of aflatoxin exposure for very young infants. The hydroxylated metabolite AFM1 is analyzed in breast milk following ingestion of foods contaminated with AFB1 after 12 to 24 hours. In the breast milk samples of lactating Iranian women the AFM1 concentrations analyzed were negatively associated with their infants' HAZ scores (correlation coefficient $\beta = -0.31$, $P = 0.01$) during the breast feeding their children exclusively [82, 83]. Along with anthropometric data the breast milk samples were collected at the first, third and fifth month following birth. And the AFM1 was analyzed in breast milk samples of 143 lactating mothers, and growth impairment in their infants fewer than 6 months of age in Northern Tanzania. AFM1 concentrations ranging from 0.01 to 0.55 ng/mL detected in all the collected samples. The potential for exposure of AFM1 from breast milk contributing to child growth impairment observed in this analysis [9, 84].

10.5 Immune suppression

In several animal species it is investigated that the immunosuppressive effects of aflatoxin reduced antibody production and cell-mediated immunity and increased the susceptibility to contagious diseases. The sIgA protects against infectious diseases and uptake of harmful micro-organisms is an important component of the mucosal barrier [85, 86]. The IgA (sIgA) antibody reduced in children with detectable AF-alb concentrations in their blood (n = 432) associated to those with non-detectable levels (n = 32) accompanied in a study in Gambia. Aflatoxin exposure reduced level of sIgA and could be a prospective mechanism for the impaired child growth that was also detected in this cohort [87, 88]. The AF-alb adduct biomarker measured high levels of aflatoxin exposure in a study of Ghanaian adults associated to those exposed to low levels of aflatoxin, had expressively lower percentages of CD3 + CD69 and CD19 + CD69 cells, and lesser percentages of CD8+ type T lymph cells that restricted perforin or both perforin and granzyme A [89]. Moreover, after modification for age and other immune parameters the negative relations were detected between CD3 + CD69 and CD19 + CD69 cells and AF-alb concentrations. Reductions in these immunological parameters could consequently lead to impaired cell-mediated immunity increasing susceptibility to infectious diseases [90–92].

11. Prevention and monitoring of aflatoxins in the food supply

During the harvest, production, storage, transport, and processing, make it problematic to eliminate prospective contamination sources of aflatoxin producing fungi in food crops. In the food supply chain the prevention of aflatoxin production is very challenging [93, 94]. Several techniques can be used to decrease risk contamination during agricultural farming and storing. For toxin-constructing

molds on seeds or in storage bowls, expending genetically resistant varieties of harvests, good practices for agronomic developments such as suitable time of irrigation and harvest, bio controls, and chemical controls [95]. For toxin-producing molds on seeds or in storing containers, using hereditarily resistant selections of crops, good agronomic performs such as suitable scheduling of irrigation and harvest, biological controls (atoxigenic strains of *A. flavus* uses), and chemical controls (fungicides application) common preharvest approaches holds analysis [96, 97]. To mold spores can reduce the risk, controlling moisture content and minimizing exposure during harvest. During storage to regulate moisture content and temperature industrial farming operations often use sophisticated equipment to mechanically dry crops [98]. For preventing aflatoxin formation farmers must consider alterations in climate, weather, crop varieties and types, and postharvest arrangement in adapting plans. Most industrialized countries to limit human exposure consistently screened for the level of aflatoxins in cultivated crops and food products [13]. The Food and Drug Administration and the U.S. Department of Agriculture monitor food provisions to assurance compliance with stringent directing restrictions first put into place in 1971, in the United States. Under tough procedures before being acceptable into food supply foods adulterated with aflatoxins above the allowable parameters must be renovated [99, 100]. Consequently, In the United States, no epidemics of acute aflatoxicosis have been documented.

12. Promising technologies for aflatoxin control

In crop production good management practices, handling, drying and storage is necessary but not sufficient for control. Because molds growth affected by several environmental factors that yields aflatoxins control is thus complex [13, 101]. For diverse production environments for integrating resistance along with required agronomic features. Both host resistance and enhanced management will require long-term efforts in research and extension for some progress is being made. To reduce the levels of aflatoxins rising during the harvesting and storage biocontrol offers a preventative measure [102, 103]. This expertise is used in United States commonly and also adopted for tropical maize and groundnuts. This newest skill technique has potential to reduce aflatoxins extensively at their initial source: in farmers' fields indicates by the field trials. Such apparatuses would expedite both public observing for aflatoxins as well as the improvement of marketable for amended-excellence grain. These new determination and diagnostic tools development are inexpensive, more dependable, and easily used in agriculture [104, 105].

13. Economic impact of aflatoxins

Aflatoxins producing fungal species such as *Aspergillus* sp. that grows and produces aflatoxins as byproducts in universal climates but commonly grown in humid and warm climatic conditions [106]. But most foodstuffs especially peanut and maize harvested in tropical countries are contaminated easily with aflatoxins. Human and animal feeds pose serious health and economic risks globally due to aflatoxin contamination. The economic impact is difficult to measure of aflatoxin contamination [107]. Developing countries of tropical and sub-tropical regions negative impact on health, economy, and social life are greater. The countries such as Gambia, Uganda, Kenya, and Tanzania, China, Thailand, Vietnam, India and

Indonesia have been classically connected with more occurrences of aflatoxins in agricultural products and foodstuffs. In U.S. $225 million/yr. impact have been estimated in maize due to aflatoxins, and in peanuts $25.8 million losses were assessed during 1993 to 1996 per year [78, 108].

14. Conclusions

In both humans and animals chronic consumption of aflatoxin-contaminated foods is a common problem. Aflatoxin exposure is the result of staple cereal crops contamination and is an important food safety issue in various countries. Acute toxicity can be lethal due to very high exposure. At any stage such as in utero, and increases during weaning naturally the chronic exposure can occur. HBV infection co-exists aflatoxin is an established risk factor, which causes the health impacts like child growth impairment and immune suppression and liver cancer. Due to aflatoxin exposure the immunosuppressive effects could increase susceptibility to contagious diseases, like diarrhea, and leading to impaired child growth due to reducing nutrient absorption. In China, Liver cancer risk has been reduced suggestively over current periods as a result of HBV vaccination and nutritional changes that reduced aflatoxin exposure. In under developing countries of south East Asia and sub-Saharan Africa where there is poor food harvesting, processing and storing thus permitting the growth of mold on them several body organs can affect due to aflatoxins.

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