JSIANE : Vol. 3, Issue 4, 2023, Page 04-21 ISSN (Online) 2583-2093

Journal of Science Innovations and Nature of Earth

Journal homepage : www.jsiane.com

Review Article

FROM FIELD TO FORKS: A DEEP DIVE INTO AFLATOXIN CONTAMINATION IN FOOD ITEMS

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www.doi.org/10.59436/jsiane.com/archives3/4/105

Abstract

Aflatoxin contamination in food items brings a significant hazard to global foodstuff safety, public health, and economic stability. This assessment comprehensively examines the sources, risks, and potential solutions associated with aflatoxin contamination in various food products. Aflatoxins, produced by moulds of the *Aspergillus flavus*, contaminate crops during cultivation, harvest, storage, and processing stages. Consumption of aflatoxin-contaminated food items has been linked to severe health issues, including liver cancer, stunted growth, and immune system suppression.

This review delves into the diverse sources of aflatoxin contamination, ranging from agricultural practices and environmental factors to storage conditions. The risks associated with aflatoxin exposure are explored in detail, emphasizing on the global impact on both human health and economies, especially in vulnerable communities reliant on staple crops. Furthermore, the review discusses multifaceted solutions aimed at mitigating aflatoxin contamination. These solutions encompass agricultural strategies such as crop rotation, improved irrigation methods, and biocontrol agents, as well as advancements in food processing techniques like sorting, washing, and hermetic storage. Regulatory measures and international standards are critically evaluated, highlighting their role in ensuring food safety and preventing aflatoxin-related health crises.

Keywords : Aflatoxin, Contamination, Public Health, Global Foodstuff Safety

Received 05.09.2023 **Revised 12.10.2023** **Accepted 20.12.2023**

Introduction

Historically, the year 1960 has been the most important, because the scientific concern about aflatoxins was generated during this year. The most prominent development in relation to aflatoxin research was the discovery of' Turkey 'X' disease which inflicted heavy loss to turkey birds in UK, when over a lakh, young turkey poults died in 1960, and the term mycotoxin was coined in England in 1962 (Stevens *et al*., 1960). The aflatoxins were first isolated in crystalline form from toxic meals by Nesbitt *et al*. (1962) and identified with the help of UV light as aflatoxin B and G, as they emit blue and green fluorescence respectively. Hartley *et al*. (1963) further identified their closely related forms as B_1, B_2, G_1 and G_2. The occurrence of natural microbial contamination in agricultural produce is a global phenomenon and among these microorganisms, fungi contribute significantly in contaminating food and feeds. Christensen (1965) categorized fungi into three distinct, groups: Field fungi, which infiltrate grains or kernels prior to harvesting in standing crop, storage fungi, which do not invade cereals before harvest but get associated during postharvest operations and then affect stored grains and advanced decay fungi, specifically found on decayed corn cobs. Pre- and post-harvest food commodity losses can be attributed to a variety of biotic and abiotic sources. Descent of stored food items by fungi is a big issue in stifling hot and humid areas. Many types of fungi, including *Aspergillus, Penicillium, Alternaria, Cladosporium, Fusarium, Mucor* and *Rhizopus*, have been found to infect harvested food grains (Mateus *et al*., 2021). Some moulds and yeasts can contaminate food when they grow in the right conditions and release harmful secondary metabolites called mycotoxins. *Aspergillus, Penicillium, Fusarium, and Alternaria* are some of the most common toxin-producing fungal taxa (Khodaei *et al*., 2021; Pandey *et al*., 2022). *Aspergillus flavus* is responsible for the production of aflatoxin B_1 and B_2, whilst *A. parasiticus*is responsible for the synthesis of aflatoxin G_1 and G_2. Cereals like maize, sorghum, rice, pearl millet and wheat; oilseeds like peanuts, soybeans, cotton, and sunflower; and spices like chilli peppers, black pepper, coriander, cumin, fennel, ginger, and turmeric are all heavily contaminated with these toxins. Also vulnerable to contamination are yams, different milk products, and nuts like almonds, pistachios, coconuts, Brazil nuts, and walnuts (Rajarajan *et al*., 2013). Mycotoxins in food have been shown to have harmful effects on human and animal health. Poultry, such as chickens and turkeys, as well as pigs and lambs, are prone to immune-suppression when exposed to aflatoxins. [CAST], 2003; Oswald *et al*., 2005 and Meissonnier *et al*., 2008). Factors determining fungal colonisation and mycotoxin biosynthesis are some environmental parameters such as water activity (aw), nutritional substrate, pH, and temperature (Schimdt *et al*., 2008). Aflatoxins are toxic carcinogenic substances generated by fungi, particularly *A. flavus* and *A. parasiticus*.

These harmful compounds have the potential to taint numerous types of animal feeds, leading to substantial economic damages. The yearly losses attributed solely to the U.S. corn industry due to aflatoxin infection are predictable to range between US$52.1 and US$1.68 billion (Jiang *et al*., 2021). Due to its carcinogenic qualities, especially its link to hepatocellular carcinoma, a type of liver cancer (Qureshi *et al*., 2015), aflatoxin B_1 poses serious hazards to the health of both humans and animals. Because they interfere with the activity of immune-boosting cells, aflatoxins have negative waves on the immune systems of both people and animals. Aflatoxins can cause death and injury almost instantly at high dosages, whereas at lower quantities they can have immunologic or nutritional consequences over time. Regardless of the dosage, accumulation of aflatoxin in the body can ultimately lead to liver cancer, as highlighted in studies conducted by Marroquín-Cardona *et al*. (2014).

Favourable conditions for aflatoxin contamination-

The production of mycotoxins is influenced by the specific food source, enzymes, and a range of environmental factors. However, it's important to note that the conditions favourable for aflatoxigenic fungi don't always guarantee the production of aflatoxins, as pointed out by Mannaa and Kim in 2017.

Aflatoxin contamination is heavily influenced by a wide range of physical parameters, including pH, moisture, light exposure, temperature, relative humidity, water availability, and atmospheric gases. Aflatoxin-producing moulds and fungi can propagate in a broad pH range of 1.7 to 9.3, with the ideal pH falling between 3 and 7 (Yoshinari *et al*., 2010). When the pH is lower, around 5, Aflatoxin B (AFB) is produced, but when the pH is higher, around 7, Aflatoxin G (AFG) is produced. Aflatoxin generation, however, is also influenced by the pH of the growth media (Dalié *et al*., 2010). Darkness enhances aflatoxin manufacture, while sunlight deters it (Rushing and Selim, 2019). Elevated vapour levels are conducive to aflatoxin contamination, as they provide favourable conditions for fungal growth. An optimal relative humidity of 85% promotes aflatoxin production, and a relative humidity of 95% significantly increases aflatoxin production (Ding *et al*., 2015). Aflatoxin fabrication can occur across a wide temperature range, but the most favourable temperature for production is between 25-35°C (Siciliano *et al*., 2017). AFB production is often higher than AFG production at higher temperatures, although AFG and AFB production levels are similar at lower temperatures (Matumba *et al*., 2015). Moreover, aflatoxin production and fungal growth are impeded in environments with elevated CO_2 levels and reduced O_2 levels (Mahbobinejhad *et al*., 2019). Substrate and dietary variables such as carbon, nitrogen, amino acids, lipids and trace elements play important roles in aflatoxin formation. Substrates rich in carbohydrates facilitate higher production compared to oil, as carbohydrates readily provide the necessary carbon essential for robust fungal growth (Ma *et al*., 2014). Increased aflatoxin formation by *A. flavus* has been linked to the addition of nitrogen in the form of nitrites and nitrates (Wang, Han, *et al*., 2017). Aflatoxin generation is increased in *A. flavus*-infected defatted wheat when maize oil is added to the media (Liu *et al*., 2016). In addition to bivalent metals like zinc and magnesium, certain amino acids like glycine, glutamate, and alanine can promote aflatoxin formation (Bolu *et al*., 2014). Zinc concentrations of 20 mg/L, 50 mg/L, and 100 mg/L were associated with 4, 5 and19 times higher levels of aflatoxin formation, respectively (Liu *et al*., 2016). Tryptophan suppresses aflatoxin formation while amino acids like tyrosine increase it (Chang *et al*., 2015). At a concentration of 0.5%, arginine, glycine, glutamic acid, and aspartic acid all contribute to the formation of AFB_1.

The quantity of aflatoxin produced is primarily determined by the specific types of fungi present. Stress caused by insect infestation in plants provides an opportunity for aflatoxigenic fungi to contaminate the affected site (Kinyungu, 2019). Aflatoxin production is also influenced by the fungal strains involved. *A. flavus* produces fewer aflatoxins in contrast to *A. parasiticus* (Manjunath and Mohana, 2018). However, *A. flavus* is the major species responsible for aflatoxin production and agricultural contamination. Compost piles, cotton, plant scraps, dead insects, field crops, stored grains, animal carcasses and animal fodder are only some of the organic nutrients it can grow on (Kakde, 2012). Notably, *A. flavus* can pollute both dicot and monocot seeds (Leger *et al*., 2000) due to its lack of host specificity. If postharvest storage conditions encourage fungus growth, more contamination of the stored crops will occur. Aflatoxin contamination was found in about 92% of the millet samples, 69% of the maize samples, and 50% of the sorghum samples studied (Sirma *et al*., 2015).

Max limits (µg/kg) established for aflatoxins in various countries for all food commodities-

Country	**Food commodity**	**Aflatoxin (max limit)**	**References**
Brazil	All edible items	15 (AFB_1)	Aiko and Mehta (2015)
China	All edible items	30 (AFB_1)	Ji *et al*. (2019)
EU	All edible items	5 (AFB_1) 10(TAF_S)	EC (2006)
India	All edible items	30 (AFB_1)	Anukul *et al*. (2013)
Indonesia	All edible items	35(AF_S), 20(AFB_1)	Ji *et al*. (2019)
Japan	All edible items	10(AF_S)	Anukul *et al*. (2013)
Malaysia	All edible items	35(TAF_S)	Srianujata (2011)

Singapore	All edible items	5(AF_S)	Anukul *et al.* (2013), Mazumder and Sasmal (2001)
Vietnam	All edible items	10(AF_S)	Anukul *et al*. (2013)
Australia	All edible items	5(AF_S)	Anukul *et al.* (2013), Mazumder and Sasmal (2001)
Sri Lanka	All edible items	30(TAF_S)	Anukul *et al*. (2013)
Thailand	All edible items	20(AF_S)	Anukul *et al.* (2013), Mazumder and Sasmal (2001)
USA	All edible items	20(AF_S)	Ji *et al.* (2019), Mazumder and Sasmal (2001)

Methods to detect aflatoxin contamination

Aflatoxins are toxic and harmful substances that can appear in food items even in very minute amounts. Eating such food products poses a number of health hazards. Thus, in order to decrease before consumption, aflatoxins must be analysed and quantified using sensitive and precise techniques (Le *et al*., 2021). Numerous analytical techniques have been used for the measurement and identification of mycotoxins in food (Berthiller *et al*., 2017). Food mycotoxin analysis is important, however it might be challenging to identify mycotoxins in vegetable oils because of their complex matrix and comparatively low amounts when compared to other meals like cereal-based products.

Chromatographic techniques-

Aflatoxins can be found in many different foods, including vegetable oils, and chromatography is a common technique for analysing them. High-performance liquid chromatography (HPLC) has been used in a number of investigations to detect AFs in food-grade oils as evidenced by research conducted by Ferracane *et al*., 2007; Afzali *et al*., 2012; F. Ma *et al*., 2013; Zhao *et al*., 2017; Nabizadeh *et al*., 2018; Karunarathna *et al*., 2019; Wang *et al*., 2019. This technique is universally applied across these investigations to analyse mycotoxin content in vegetable oils and other food items. Thin-layer chromatography (TLC) proves to be a cost-effective and straightforward mode for both qualitative and quantitative analysis of various mycotoxins, benefiting from its affordability, simplicity, and the presence of UV light fluorescent spots, as noted in the study by Janik *et al*. (2021). However, its limited sensitivity and accuracy pose challenges in precise quantification, as highlighted by Singh and Mehta in 2020. To address these limitations, liquid chromatography (LC) attached with tandem mass spectrometry (MS/MS) stands out as a reliable analytical approach. This method combines the efficient separation capabilities of LC with the high sensitivity of MS/MS, according to research, it is a useful method for simultaneously identifying and measuring mycotoxins in different matrices Adebo *et al*. (2018) and Gbashi *et al*. (2019). Specifically, for the quantification of different mycotoxins (AFB_2, AFB_1, AFG_2, AFG_1, OTA, ZEA, DON) in grain legumes, LC-MS/MS was employed, as described in the study conducted by Kunz *et al*., 2020. The limits of detection (LOD) for AFs using HPLC-FLD varied across studies. Elzupir *et al*. (2010) reported LODs ranging from 0.09 to 1.5 µg/kg, while Afzali *et al*. (2012) achieved LODs of 0.11 to 5.3 ng/L. Additionally, Nabizadeh *et al*. (2018) recorded LODS of 0.04 to 0.16 µg/kg, Karunarathna *et al*. (2019) observed LODS of 0.01 to 0.04 µg/kg, Wang *et al*. (2019) reported LODS of 0.005 to 0.03 µg/L, and F. Ma *et al*. (2013) noted LODS of 0.03 to 0.25 µg/kg in different matrices, employing diverse preparation methods. Afzali *et al*. (2012) achievement of the lowest LODS may be attributed to their effective cleanup procedures and more selective extraction methods. In a study conducted by Hidalgo-Ruiz *et al*. (2019), mycotoxins (AFB_1, AFB_2, AFG_2, and AFG_1) were analysed in 194 samples of corn oil, soybean oil, olive oil, and sunflower oil. The researchers employed UHPLC-QqQ-MS/MS coupled with the QuEChERS procedure for the analysis.

Immunochemical and biosensor techniques-

In addition to chromatographic methods, immunochemical assays and biosensors are gaining popularity for analysing mycotoxins in oil samples. Immunochemical detection relies on the unique binding between antibodies and antigens, encompassing a range of techniques from ELISA and basic lateral flow immunoassays (LFIA) to more sophisticated immunosensors (Turner *et al*., 2015).

ELISA, a technique based on competitive reactions between antigens (such as mycotoxins) and antibodies, is a straightforward and relatively quick method. Qi *et al*. (2019) utilized ELISA to detect AFB_1 in peanut oil, achieving a LODS of 1.08 µg/kg, Positive ELISA results (>20 µg/kg) were cross-verified using the more sensitive UPLC-MS/MS method (with a LODS of 0.01 µg/kg). Additionally, ELISA has been employed to measure AFB_2, AFB_1, AFG_2, and AFG_1 levels in various oils such as coconut oil, soya bean oil, palm kernel oil, melon oil and groundnut oil. The findings revealed that the concentrations of AFs in all samples were below the regulatory limits, as demonstrated by Malu *et al*. (2017). Selective mycotoxins detection is achieved through the utilization of IAC (Immunoaffinity Columns), where specific monoclonal antibodies are employed, these antibodies bind to the target mycotoxin on the column. Subsequently, the mycotoxins are extracted from

the column using pure acetonitrile or methanol, as described in the study by Liu *et al*. (2018). In a similar manner, IAC was applied for the analysis of AFs in wheat bran, as detailed in the research conducted by Irakli *et al*. (2017).

Wang, Li *et al*. (2017) devised a highly precise nanobody-polyclonal antibody sandwich ELISA method to identify both *A. flavus and A. parasiticus*, achieving an impressive minimum detection limit of 1 µg/ml. Subsequently, genes linked to Aflatoxin biosynthesis in *A. flavus* were targeted using multiplex PCR during molecular screening to detect aflatoxin. To further enhance detection, the Visible/Near-Infrared technique (VNIR) was employed to identify toxin contamination. In various regions of North America, significant levels of AFB_1 were discovered on maize kernel's surfaces through VNIR analysis (Chu *et al*., 2017). However, due to the limitations in image quality associated with VNIR, recent studies have concentrated on the joint utilization of Hyperspectral Imaging (HSI) and chemometric data analysis. This integrated approach has led to improved identification of AFB_1 on maize kernels' surfaces, as demonstrated by Kimuli *et al*. (2018). Various techniques employing nanoparticles such as quantum dots (QD), carbon-based nanomaterials (CBNs), and Au/Ag are employed to identify different aflatoxins in crop plants, as outlined by Xue *et al*. (2019). Biosensors employ biological molecules like enzymes, antibodies, bacteria, and DNA for both recognition and transduction purposes. Biosensors offer a cost-effective, efficient solution for aflatoxin detection, requiring minimal sample preparation and enabling quick and straightforward identification. These biosensors utilize an electrochemical enzyme- linked oligonucleotide array, allowing for portable and on-the-spot aflatoxin identification, as demonstrated in studies by Rotariu *et al*. (2016) and Selvolini *et al*. (2019).

Biosensors predominantly depend on two primary detection techniques, optical and electrochemical methods, for identifying mycotoxins (Yang *et al*., 2020). Presently, the prevailing direction involves optical biosensors that utilize chemiluminescent approaches. Specifically, these can be categorized into CLIA (chemiluminescent immunoassay) and CLEIA (chemiluminescent enzyme immunoassay). Different biosensor variations, including aptamer and surface plasmon resonance types, have been utilized in mycotoxin detection within oils, as demonstrated in studies by Q. Chen *et al*. (2018), Lu *et al*., 2015; X. Xia *et al*. (2018), and Zhu *et al*. (2015). A groundbreaking amperometric biosensor, incorporating the acetylcholinesterase (AChE) enzyme, was employed to identify AFB_1 contamination in olive oil. This innovative method yielded a limit of detection of 0.3 µM, along with reliable recovery data (Rejeb *et al*., 2009). Meanwhile, Ma *et al*. (2015) pioneered a fluorescent aptamer for AFB_2 detection, utilizing aminated Fe_30_4 magnetic nanoparticles. Their findings indicated that the selected aptamer could detect AFB_2 with a remarkable LOD of 50 ng/L. Additionally, in studies conducted by Lu *et al*. (2015), a Graphene oxide-aptamer-Q-dots fluorescence quenching system was employed, resulting in LODS of 1.0 nM for AFB_1 in aqueous systems and 1.4 nM for peanut oil.

Aflatoxins in some important food commodities:

Maize –

Maize in West Africa showed significant contamination by AFs, with varying levels recorded in different countries. In Ghana, AFs levels ranged from 0.4 to 490 µg/g, in Benin from 0.2 to 120 µg/g, and in Togo from 0.7 to 110 µg/g (James *et al*., 2007). Alarmingly, 4 out of every 5 maize samples from the Southern Guinea Savanna surpassed the international recommendation of 20 µg/g, set by global authorities. In India, out of 190 samples studied for multiple mycotoxin contamination, 34.8% were predominantly tainted by AFs, with 69 samples exceeding the permissible limits (Janardhana *et al*., 1999). Moreover, stored maize grains exhibited a high AFs presence, with 43% of samples showing contamination, most of which exceeded 20µg/kg. Specifically, samples from Egypt displayed 30 µg/kg of TAFs (Abdelhamid, 1990), those from Southern Guinea contained 77 µg/kg (Hell *et al*., 2003), and maize obtained in Croatia between 1996 and 1997 exhibited AFB_1 levels ranging from 224 to 614 µg/kg (Jurjevic *et al*., 2002). Notably, Croatia had the highest percentage of OTA positive samples (25%), indicating a significant OTA concentration of 31.7 µg/kg (Segvic *et al*., 2009). A research study conducted in Italy between 1995 and 1999 uncovered alarming levels of AFs in maize samples. Two specific samples exhibited extraordinarily high AFB_1 levels, ranging from 109 to 158 µg/kg. On average, the seeds had AFs concentrations spanning from 0.3 to 4.10 µg AFB_1/kg (Pietri *et al*., 2004). Similarly, samples from Turkey displayed significant contamination, ranging from 120.3 to 133 µg/kg (Giray *et al*., 2009). Furthermore, a study conducted in Syria found AFS levels surpassing the 20 µg/kg threshold (Majid, 2007).

Study conducted by Shah *et al*. (2010) revealed that the concentration of aflatoxin B_1 ranged from none to 30.92 µg/kg, with higher averages observed in the upper Swat regions (average 14.94 µg/kg) and lower Swat regions (average 16.22 µg/kg). Out of the 24 stored maize samples, 12 were found to be contaminated with aflatoxin B_1. The levels of contamination ranged from 2.30 to 30 ppb as determined by TLC and from 270 to 500 ppb as determined by ELISA techniques (Hassan *et al*., 2014). According to Kos *et al*. (2020) out of the 20 fungal metabolites examined, 20, 17, 13 and 17 were detected in maize samples collected in the years 2012, 2013, 2014 and 2015, respectively. Nsabiyumva *et al*. (2023) observed that merely a 3% fraction of maize exhibited aflatoxin levels surpassing the 10 µg/kg EAC limit.

Wheat-

In Several regions of Turkey, 41 wheat samples were collected and analysed. The results revealed the presence of *Aspergillus flavus* and *Aspergillus parasiticus* contamination, along with the production of AFs including B_2, B_1, G_2 and G_1, ranging from 10.6 to 643.5 µg/kg as reported by Giray *et al*. in 2007. Out of these samples, 59% tested positive for TAFs, namely B_2, B_1, G_2 and G_1 with individual percentages of 12%, 42%, 12%, and 37%. Additionally, various newly identified mycotoxins were also detected in these wheat samples. In 48 out of 185 tested wheat samples, AFB_1 was detected, constituting 25.9% of the samples. The concentration of AFB_1 varied between 0.05 mg/kg and 4.78 mg/kg, averaging at 0.51 ± 1.14 mg/kg. AFB_2, on the other hand, was present in only 13 samples, accounting for 7.0% of the total. The mean AFB_2 level in these samples was 0.02 ± 0.08 mg/kg, and the contamination ranged from 0.02 mg/kg to 0.48 mg/kg (Asghar *et al*., 2016). Wheat faces various challenges throughout its growth and storage phases, primarily due to mycotoxin contamination. These toxins not only taint the wheat but also pose significant risks to both humans and animals when consumed as food or feed (Ghangro *et al*., 2016).

Ghasemi-Kebria *et al*. (2013) performed a study on wheat flour in high -risk area of Iran and found that in all wheat flour samples, the average levels (standard deviation) of AFB_1, AFB_2, AFG_1, AFG_2, and total aflatoxins were 0.53 (0.88) ng/g, 0.31 (0.71) ng/g, 0.55 (0.93) ng/g, 0.6 (0.6) ng/g, and 1.99 (1.96) ng/g, respectively. during the summer season, the average total aflatoxin concentration in samples was 0.82 ng/g, whereas in winter, it rose to 1.99 ng/g. In summer, 3.1% of samples exceeded the globally accepted limits for Aflatoxin B_1, while in winter, this percentage increased to 7.4%. Aflatoxin contamination was most prevalent in winter samples, specifically aflatoxin B_2 (98%), while in summer, aflatoxin G_1 was more common, affecting 51% of the samples (Tahri *et al*., 2012). Among the 108 samples analysed, 30.6% (38 samples) tested positive for at least one type of aflatoxin. Aflatoxin B_1 was the most prevalent, present in 27.8% of the samples, with the highest concentration recorded in a grain sample at 4.2 µg/kg. Aflatoxin G_1 and G_2 were found in 10.2% and 0.9% of the samples respectively (Trombete *et al*., 2014).

Rice-

In a study from 1990, Jayaraman and Kalyanasundaram discovered that parboiled rice bran and rice bran samples contained up to 35% AFB_1. Rice samples were found to have higher levels of AFs (ranging from 184 to 2,830 µg/kg) compared to wheat and maize samples in a study conducted by Pande *et al*. 1990. A separate study by Liu *et al*. 2006 analysed 36 de-husked brown rice samples, revealing the presence of AFB_2, AFB_1, AFG_2 and AFG_1 at levels ranging from 0.99 to 3.87 µg/kg. Research conducted in India by Reddy *et al.* (2009a) indicated that 67.8% of the examined rice and paddy samples were positive for AFB_1, with toxin levels ranging from 0.5 to 38.5 µg/kg. Additionally, a study by Siruguri *et al.* (2012), focused on rice samples from six districts in Punjab, found that the PAU 201 variety of stored rice had AFB_1 levels below 15 µg/kg. In a subsequent study, Iqbal *et al*. (2016) examined 62 samples in Pakistan and discovered that 37% of these samples had AFB_1, with concentrations varying between 0.04 and 21.3 µg/kg. In Nigeria, Hussaini *et al.* (2009a) detected AFs in 97 out of 196 collected samples, with AF levels ranging from 24 to 1,164 µg/kg. Majeed *et al.* (2013) found that 50% of the examined rice samples were contaminated with AFs at levels ranging from 0.05 to 24 µg/kg. Another study by Majeed *et al*. (2018) identified 23 mycotoxins in 180 rice samples, with AFs being prevalent in 20-56% of the samples. The levels of aflatoxin B_1 and total aflatoxins in the examined rice samples were below 0.123 mg/kg and 2.58 mg/kg, respectively (Al zoreky *et al*., 2017). From a total of 413 rice samples, including 58 paddy, 69 parboiled, 84 brown, 93 white, and 109 broken rice samples, aflatoxin contamination was present in 64% of paddy samples at an average concentration of 16.35±1.67 µg/kg, 38% of parboiled samples at 14.20±2.04 µg/kg, 33% of brown samples at 9.85±1.25 µg/kg, 42% of white samples at 7.10±1.39 µg/kg, and 50% of broken samples at 8.5±1.71 µg/kg (Iqbal *et al*., 2012). In various regions of China, including Huantai, Huaian and Fusui, aflatoxin B_1 was detected in all 29 rice samples, with an average contamination level ranging between 0.5-0.6 mg/kg, as reported by Sun *et al*. (2011). These findings align with earlier research by Wang and Liu in 2007, which indicated contamination at an average of 0.79 mg/kg. Conversely, South Korea showed significantly lower contamination levels. Out of 88 samples, only 5 were found to be contaminated, with mean values as low as 4.8 ng/kg, according to Park *et al*. (2004).

In contrast, rice samples from India displayed higher aflatoxin levels. A survey across 12 states revealed that out of 1511 samples, 256 exceeded the Indian permissible limit of 30 µg/kg for total aflatoxin, with 930 samples above 5 µg/kg and a median concentration of 45 µg/kg, as reported by Toteja *et al*. (2006). However, more recent studies in Punjab, India, conducted by Siruguri *et al*. (2012), indicated acceptable aflatoxin levels. The distribution of aflatoxins in Malaysia resembled that of China and the Philippines, 9 out of 13 samples in Malaysia exhibited aflatoxin B_1 contamination, averaging at 1.75 µg/kg (Reddy *et al*., 2011). In contrast, Japan reported a different scenario, with all 83 rice samples found to be free from any type of aflatoxin, as stated in the research by Kumagai *et al*. (2008).

Peanuts:

Peanuts, globally recognized as the second most crucial legume following beans which face significant challenges due to inadequate storage methods. These challenges result in the emergence of mycotoxins, notably AFs, as highlighted in various studies (Kaaya *et al*., 2006). Studies in India reported AF levels surpassing 30 µg/kg in various peanut samples (Kishore *et al*., 2002). Aflatoxins types B and G, have been identified in peanuts cultivated in Argentina's Formosa province by *Aspergillus flavus* (Pildain *et al*., 2004). Research conducted by Gonçalez *et al.* (2008) indicated AF levels ranging from 4.20 to 198.8 µg/kg, surpassing the USDA's maximum limit of 20 µg/kg in 90% of the samples examined by Ezekiel *et al.* (2012). Nakai *et al.* (2008) detected aflatoxin in 6.7% of the hull samples, specifically aflatoxin B_1 and B_2, while 33.3% of the kernel samples were contaminated with aflatoxin B_1 and B_2. The peanut cake samples showed AFs levels ranging from 10 to 346 µg/kg, with OTA levels remaining below the quantification limit of 2 µg/kg (Ediage *et al*., 2011). Babu *et al.* (2011) showed that 55% of the aflatoxin present in the crude production consisted of the following ratio - B_1: B_2: G_1: G_2, with proportions of 100:0.15:0.22:0.02. Additionally, groundnuts from Ethiopia exhibited AF levels ranging from 15 µg/kg to a staggering 11,900 µg/kg (Chala *et al*., 2013). Mohammed *et al.* (2016) found that, in the 2013/2014, 22.5% of the groundnut samples were found to be contaminated with aflatoxin, with an average concentration of 786 ng/g. However, in 2014/2015, 41.3% contamination was observed, with an average aflatoxin concentration of 3135 ng/g. Maringe *et al.* (2017) found that 12.5% of the groundnut samples were contaminated with aflatoxin, with contamination levels ranging up to 175.9 µg/kg by using HPLC. In Nigeria, investigations revealed TAFs content in groundnut cakes, roasted groundnuts, and boiled groundnuts at 11.15 µg/kg, 4.50 µg/kg, and 1.51 µg/kg, respectively, indicating that groundnut cakes had the highest incidence and concentrations of TAFs (Adefolalu *et al*., 2021). Furthermore, these studies found that AF levels increased with prolonged storage duration.

Pulses and oilseed crops-

Research findings indicate that *Aspergillus* species have been found to produce varying amounts of AFB_1 in pulses and oilseed crops, ranging from 333 to 10,416 µg/kg (Begum and Samajpati, 2000). Another study examined 66 isolates of *Aspergillus flavus* from mustard seeds, revealing that 24 of these isolates produced AFs, with levels ranging from 0.25 to 22 µg/ml. Among these, eight isolates exhibited remarkably

high AF levels, while the remaining 16 isolates produced considerably lower amounts of AFs. Additionally, *Aspergillus parasiticus* from bean seeds were identified to produce significant concentrations of AFs (196.58 µg/kg as observed in the research conducted by Embaby *et al*. (2013). Further 4.3% of the cowpea samples showed aflatoxin contamination with levels ranging from 1.4 to 103.4 µg/kg (Maringe *et al*., 2017). In a recent study in Nigeria, 81 cowpea samples were analysed, with all of them testing positive for Afs and the AFs concentrations ranged from 84 to 209 µg/kg (Afolabi *et al*., 2019). In a study conducted by Nazir *et al*. (2019) on pulses revealed aflatoxin contamination in split chickpea, lentils, black gram beans to the extent of 11.2 ppb, 8.6ppb and 15.4 ppb respectively.

Fruit and fruit juices-

Apart from cereals, pulses, oil seeds and spices there is a potential risk of toxin contamination in fruits and fruit juices. *Aspergillus* species are well-known for producing toxins in fruits. Raisins in Brazil, Egypt, Greece, India and Morocco have been found to contain AFB_1 with concentrations ranging from 2 to 550 µg/kg (Saxena and Mehrotra, 1990; Juan *et al*., 2008). The analysis of chloroform extracts from five distinct fruit juices and beverages (five samples each) using thin-layer chromatography showed that all five tested apple beverages were tainted with aflatoxin B and G. The concentrations of these contaminants ranged from 20-30 µg/L. Additionally, two out of the five guava juice samples tested were naturally contaminated with aflatoxin B at a concentration of 12 µg/L. (Abdel- sater *et al*., 2001).

Natural contamination by aflatoxin has been observed in various fruits and fruit products. Oranges, apples, and apple juices have been reported to be affected (Drusch and Ragab, 2003). Reports suggest that grapes, specifically may contain significant levels of AFs (0.3%) and OTA (6.0%) as indicated by Serra *et al*. (2005). Aflatoxin B_1 (AFB_1) contamination has also been documented in grape juices and musts (EL Khoury *et al*., 2008). Dried figs and raisins are most commonly affected and AFB_1 has been found in apricots, prunes, and dates as well (Trucksess and Scott, 2008). Out of the 30 mycotoxins examined, only 9 were found in measurable quantities in 49% of the analysed juices. These primarily included AOH, AME, PAT, OTA, AFB_1, AFB_2, AFG_2, ZAL, and HT-2 (Pallares *et al*., 2019).

Other food commodities-

Dixit (2009), uncovered the presence of 30 different fungal species in fenugreek seeds, of which *Aspergillus flavus* was abundant and found that out of 101 isolates 61.2% showed aflatoxicity. Chauhan, (2012) analysed 50 samples (30 stored and 20 fresh) of Safed musli (*Chlorophytum borivilianum* L.), 12 out of 30 stored samples contained 9 to 50 µg/kg of AFB_1, and 2.00 to 4.40 µg/kg of AFB_2 in association with AFB_1. Fresh samples contained AFB_1 in the range of 0.1 to 2.60 µg/kg. Sharma *et al*. (2013) isolated 35 strains of *Aspergillus flavus* from chilgoza seeds (*Pinus gerardiana* Wall.), they found aflatoxin with a mean value ranging from 0.737±0.023 to 1.675±0.486 µg/g. According to Odongo *et al*. (2018); Chaudhari *et al*. (2020) and Schabo *et al*. (2020) noted that chia seeds are severely infected by a variety of storage fungi and associated compounds including aflatoxin (mostly aflatoxin B_1), during storage.

Njeri *et al*. (2019) performed a study on chia seeds cultivated and sold in Kenya, they found the moulds count ranged from 1.33 $x10^3$cfu/ml -2.67 x 10^3cfu/ml. Jermnak *et al*. (2020) found AFs in 40% of the total samples, with value ranging from of 04 to 10.99 ng/g. Three of the positive samples were found to surpass the European Union's regulatory limit (4 ng/g) for total AFs. The most commonly detected AF in chia seeds was AFB_1. Senthilkumar *et al*. (2021) found that 52.07% samples of pearl millet contained aflatoxin B_1. A co-occurrence of aflatoxin B_2 was detected alongside aflatoxin B_1 in 28.93% of the samples. On numerous occasions, *Aspergillus nigri* species were commonly obtained from various vineyards in Argentina. Investigations conducted on red grapes harvested from Mendoza vineyards indicated that species belonging to the *A. niger* aggregate were prevalent. Levels of aflatoxin G_1 reaching up to 78 mg/kg and aflatoxin B_1 reaching up to 63 mg/kg have been detected in eggs at various stages of production. Ozay *et al*., 1991. Magnoli *et al*. (2003) and Houissa *et al*. (2019) found that out of 220 pearl millet samples analysed 91.4% grain samples contain fungal metabolite contamination. Among major mycotoxins, AFB_1 was present at an average level of 106 µg/kg exceeding the European thresholds of 5 µg/kg. Lahouar *et al*., (2018) found that out of 64 samples, 38 samples of sorghum were contaminated with aflatoxin ranging from 0.03 – 31.7 µg/kg. Spanjer *et al*., 2008 found LODS 0.5-200 µg/kg for aflatoxin in pistachio nut and peanuts. Ssepuuya *et al*., (2018) studied aflatoxin contamination in sorghum and found mean concentration of AFB_1 to be 42.6 ± 58.8 µg/kg, AFB_2 to be 78.7 ± 9.34 µg/kg, ABG_1 to be 41.3 ± 110 µg/kg, AFG_2 to be 13.7 ± 9.49 µg/kg. In a study performed by Shetty and Bhatt, (1997), AFB_1 concentration in sorghum was found to be 5 to 125 µg/kg. Plants and their derived products, such as medicinal herbs, tea, and spices, often contain considerable levels of AF contamination, reaching up to 2,230 µg/kg, particularly noticeable in liver-healing herbal remedies sold in India (Trucksess and Scott, 2007). Zinedine *et al*. (2006) detected the natural occurrence of AFB_1 in Moroccan black pepper, ginger, red paprika, and cumin, averaging at 0.09, 0.63, 2.88, and 0.03 µg/kg, respectively. Among these, red paprika exhibited the highest contamination level at 9.68 µg/kg. Singh and Cotty, (2017) conducted a study on 33 chili samples obtained from markets in both the United States and Nigeria and revealed that AFB_1 was present in 64% of the chili samples from US markets and in 93% of the Nigerian chili samples. Among the US samples, 2% exceeded the regulatory limit for aflatoxin, which is set at 20 µg/kg, with the highest detected concentration reaching 94.9 µg/kg. Sumon *et al*., (2021) found AFM_1 in 78.6% of dairy products, ranging from 5.0 to 198.7 ng/L. Within raw milk, AFM_1 was identified in 71.4% of samples (with an average of 41.1 ng/L and a range of 5.0-198.7 ng/L), while it was present in all pasteurized milk (with an average of 106 ng/L and a range of 17.2-187.7 ng/L) and UHT milk (with an average of 73 ng/L and a range of 12.2-146.9 ng/L) samples.

Aflatoxin Level Detected In Major Food Commodities-

Food Crop	Type of aflatoxin	Aflatoxin concentration	References
Corn	Total AFs	1.01-86.10 ppb	Kos *et al*. 2013
Rice	AFB_1	37.26–113.20 ppb	Anthony *et al*. 2014
Wheat	AFB_1	2.3 ppb	Al-Wadai *et al*. 2013
	AFB_2	2.6 ppb	
	AFG_1	1.3 ppb	
	AFG_2	0.5 ppb	
Red chilli	AFB_1	0.24-165 ppb	Golge *et al*. 2013
	AFB_2	0.15-11.3 ppb	
	AFG_1	0.15-3.88 ppb	
Maize	AFB_1	188 µg/kg	Aristil *et al*. (2020)
Sorghum	AFB_1	2 µg/kg	Lahouar *et al*. (2018)
Pearl millet	AFB_1	106 µg/kg	Houissa *et al*. (2019)
Cashew nuts	Total AFs	0.60-31.50 ppb	Milhome *et al*. 2014
Groundnut	AFB_1	72.97-195.17 ppb	Magembe *et al*. 2016
Rice	AFB_1	0.04-21.30 ppb	Iqbal *et al*. 2016
Sunflower	AFB_1	28 ppb	Mmongoyo *et al*. 2017.
Lentils	AFB_1	0.57-1.74 ppb	Baydan *et al*. 2016
Figs	AFB_1	0.1-12.5 ppb	Kabak 2016
	AFB_2	0.07-0.72 ppb	
	AFG_1	0.08-15.3 ppb	
	AFG_2	0.1-0.38 ppb	
Mango seeds	Total AFs	61.7 ppb	Ezekiel *et al*. 2016
	AFB_1	68.1 ppb	

Food Crop	Type of aflatoxin	Aflatoxin concentration	References
Chickpea	AFB_1	167.4 µg/kg	Mohana *et al.* (2017)
Hazelnut	AFB_1	56 ppb	Diella *et al*. 2018
Almond	AFB_1	72 ppb	Diella *et al*. 2018
Apricot	AFB_1	56.3 ppb	Diella *et al*. 2018
Pistachio	AFB_1	48 ppb	Diella *et al*. 2018
Strawberry	AFB_1	24.7–51.8 ppb	Saleem 2017
	AFB_2	25.8–58.9 ppb	
	AFG_1	33.0–75.2 ppb	
	AFG_2	31.2–71.1 ppb	
Black pepper	AFB_1	39.7–65.9 ppb	Nazir *et al.* 2019
Coriander	AFB_1	33.4–67.9 ppb	Nazir *et al.* 2019
Cumin	AFB_1	24.9–63.9 ppb	Nazir *et al.* 2019
Aniseed	AFB_1	35.3–52.5 ppb	Nazir *et al.* 2019
Soyabean	AFB_1	1.50 ppb	Pratiwi *et al.* 2015
	AFB_2	0.88 ppb	
	AFG_1	0.18 ppb	
	AFG_2	0.43 ppb	
Ginger	Total AFs	0.11-9.52 ppb	Lippolis *et al*. 2017.
Guava	AFB_1	0.163 ppb	Embaby and Hassan 2015
	AFG_1	0.296 ppb	

Techniques for removing Aflatoxins from food products-

In the past few years, it has become essential to decontaminate mycotoxins particularly aflatoxins in food items because of their harmful impact on human and animal health. Across the globe, various methods such as chemicals, physical treatments, botanical solutions and biological approaches have been investigated to detoxify aflatoxins from contaminated food products. Despite numerous techniques being researched, only limited techniques have been practically implemented. Essential oils, botanical extracts, irradiation, ozone medication, pulsating light, freezing plasma, and microbiological procedures are only some of the novel ways for decontamination highlighted in this overview.

Physical methods of decontamination of Aflatoxins -

Cold plasma-

Cold plasma stands out as an innovative and non-thermal method, generating reactive species like O, O_3, NO, OH and NO_2, which effectively break down Aflatoxins and transform them into less harmful compounds. This process offers numerous advantages, including preserving the quality of food products, as highlighted by Mir *et al*. (2021). In a study by Wielogorska *et al.* (2019a), a 65% reduction in AFB_1 and a 64% reduction in FB_1 in maize were achieved after a brief cold plasma treatment lasting 10 minutes at 20 Hz. Consequently, cold plasma exhibits promising potential as a mycotoxin decontamination strategy for various food commodities. Using the CP method, researchers were able to

eliminate 70-73% of injected AFB_1 in hazelnuts (Sen *et al*., 2019). However, despite these promising attributes, these technologies come with certain limitations. Challenges such as protein oxidation, lipid oxidation, alterations in food colour, and changes in sensory properties hinder their widespread adoption within the food industry, as noted by Olatunde *et al*. (2021).

Irradiation –

Another method employed for mycotoxin decontamination in food products is irradiation, utilizing ionizing energy. While effective and non-thermal, irradiation can lead to the oxidation of lipids or vitamins, as well as the development of off-flavors and alterations in food colour, as pointed out by Mir *et al*. (2021). Gamma irradiation has been utilized on various cereals such as barley, maize, wheat, and rice, primarily to reduce AFB_1 levels, with studies by Aziz *et al*. (2004); Aquino *et al*. (2005) and Mohamed *et al*. (2015) providing evidence. However, it is worth noting that this method might not always eliminate all mycotoxin-producing fungi. Exposure to gamma radiation has been proven to decrease aflatoxin levels, as indicated by Aquino in 2011. Additionally, ultraviolet (UV) irradiation within the 220-400 nm wavelength range effectively degrades aflatoxins, notably AFB_1, AFB_2, and AFM_1, in diverse crops. Studies by Diao *et al*. (2015) demonstrated degradation rates ranging from 77 to 99.12%.

Pulsed light treatment-

The pulsated light technology, heralded as innovative and full of promise, boasts several advantages. Notably, it leaves no residues in food products, proving to be cost-effective. However, its decontamination action is limited to the surface of foods and has the additional effect of inhibiting seed germination, as highlighted by Mir *et al*. (2021). Research by Wang B. *et al*. (2016) demonstrated a 75% reduction in AFB_1 and a 39% reduction in AFB_2 in rice subjected to pulsed light at a dosage of 0.52 J/cm^2/pulse for 80 seconds. This technology has also been combined with citric acid to effectively degrade AFs in peanuts, as evidenced by the study conducted by Abuagela *et al*. (2019). Despite these advantages, one of its primary drawbacks lies in its limited penetration power.

Other heat treatments-

Research has shown that several strategies, including the use of steam under pressure, dry roasting process, and other methods for cooking, have been successful in reducing or managing aflatoxin contamination in a variety of crops Peng *et al*. (2018). Significant reductions in aflatoxin levels have been observed through these methods. For instance, heating seed samples at 180°C led to a reduction of about 40-73% (Opoku, 2013). Roasting groundnut and corn seeds with 30% moisture at 100°C for 2 hours resulted in an impressive 85% decrease in aflatoxin content (Leong *et al*., 2010). Additionally, roasting seeds at 150 °C for 15 minutes led to a 70% reduction in AFB_1 and a 79% reduction in AFG_1 concentrations (Jalili, 2016). Furthermore, exposing artificially infected maize and groundnut seeds to sunlight for 10-12 hours led to an 80% reduction in AFB_1 and a 17% reduction in groundnut aflatoxin content (Rushing and Selim 2019).

Chemical techniques for aflatoxin removal:

The most effective strategy to prevent aflatoxin contamination in food commodities is through proactive prevention rather than relying solely on detoxification or decontamination methods. This prevention primarily hinges on proper agricultural practices. However, in many instances, it is challenging to entirely prevent fungal growth, which ultimately leads to aflatoxin formation. but it can reduce aflatoxin levels in multiple food items, as indicated by the research of Carvajal and Castillo (2009).

Bedi and Agarwal (2014) described the use of sodium bisulfite (0.5%) and sodium hydroxide (1%), respectively to remove aflatoxin from groundnut cake and chicken feed. Aiko and Mehta (2015) found that the growth of *A. flavus* and the formation of aflatoxin were suppressed by the addition of preservatives such as p-amino benzoic acid, propionic acid, crystal violet, boric acid, benzoic acid, and sodium acetate. To reduce its mutagenic potential, AFB_1 can be detoxified with citric acid by undergoing acid-catalyzed processes to convert it into a beta-keto acid structure, followed by hydrolysis of the lactone ring (Mendez-Albores *et al*., 2005). This yields AFD_1, a molecule with reduced mutagenic potential. Hydrogen peroxide, ozonated water, and propionic acid are some other chemicals that can be used in these processes. When it comes to getting rid of mycotoxins without leaving behind any harmful byproducts, ozone therapy stands out as a top option. For instance, wheat treated with ozone at a dosage of 60 mg/L for 300 minutes reduced AFs by 48%, according to a study by Trombete *et al*. (2017). In a similar vein, Savi *et al*. (2014, 2015) treated wheat samples with 60 μmol/mol of ozone gas for 180 minutes, resulting in significant reductions of both AFB_1 (94.6%) and AFB_2 (84.5%), and for AFG_1 (80%) and AFG_2 (81%).

The research by Karlovsky *et al*. (2016) showed that ammoniation procedures in maize and other food commodities can reduce the generation of aflatoxins. According to the study conducted by Broková *et al*. (2015), several compounds such as formaldehyde, sodium bisulfite, calcium hydroxide, sodium borate, sodium hypochlorite, and sorbents have proven too substantially.

Various propionic acid salts, such as calcium and sodium propionates, have demonstrated the ability to diminish aflatoxin formation in maize, as evidenced by the study conducted by Hassan *et al*. (2015). Moreover, in groundnut cake, *Aspergillus flavus*-induced aflatoxin generation was suppressed by weak acids including citric acid, acetic acid, propionic acid, and sorbic acid at concentrations ranging from 0.25% to 1%, according to research conducted by Verma *et al*. (2000). In addition, azole fungicides have been used successfully to curb fungal expansion and aflatoxin formation, with prochloraz proving more efficient than tebuconazole, as reported by Mateo *et al*. (2017).

Biological methods of detoxification of aflatoxins-

Various biological agents, including bacteria, yeasts, moulds, and algae, display diverse capabilities in degrading aflatoxins within specific environments. The detoxification of aflatoxins through biological agents involves two processes: absorption and enzymatic breakdown, as detailed in the research by Jard *et al*. (2011). Biological approaches are eco-friendly and don't produce harmful residues, yet choosing non-toxic microorganisms for detoxification is challenging, and the process takes a longer time, as indicated by Mir *et al*. (2021).

Microorganisms such as *Bacillus subtilis*, *Bacillus licheniforms*, and *Saccharomyces cerevisiae* have been used to decontaminate food items. Microorganisms can directly absorb aflatoxins by binding them to their cell wall components, as demonstrated in the study by Motawe *et al*. (2014). Furthermore, aflatoxins can be absorbed even by

deceased microorganisms, a feature utilized in fluid decontamination processes, as observed in the research by Mwakinyali *et al.* (2019). Additionally, aflatoxins can undergo degradation through intra or extracellular enzymes, as explored in the study conducted by Aliabadi *et al.* (2013). The strain *Bacillus velezensis* DY3108's cell-free supernatant demonstrates robust AFB_1 degradation, achieving a remarkable 91.5% reduction, as reported by Shu *et al.* (2018). In the realm of thermophilic bacteria, strains like *Geobacillus* and *Tepidimicrobium* prove highly effective in degrading AFB_1, especially when utilized together as a microbial consortium, as highlighted by Wang, Zhao *et al.* in 2017. Furthermore, pre-harvest crops experienced a significant decrease in *A. flavus* growth through the introduction of antagonistic strains like *Trichoderma*, *Pseudomonas, Lactobacilli, Ralstonia, Burkholderia*, and *Bacillus* spp., as noted in the research by Akocak *et al.* (2015) and Yang *et al.* (2017).

In the study conducted by Ansari *et al.* (2015), kefir-grains were employed to decrease AFB_1 contamination in pistachios by an impressive 96.8%. Similarly, Farzaneh *et al*. (2012) utilized *Bacillus subtilis* UTBSP1 in the same context, achieving a notable 95% reduction in AFB_1 levels.

Essential oils for detoxification of Aflatoxins -

Several studies have shown that essential oils can be used to prevent *A. flavus* and *A. parasiticus* from expanding and producing aflatoxins. For instance, Maraqa *et al.* (2007) and El-Nagerabi *et al*. (2012) have examined this strategy. Complete inhibition of AFs generation in maize was seen using extracts of *Azadirachta indica* seeds at 500 and 1,000 mg/kg, and extracts of *Morinda lucida* seeds at the same dose (Bankole, 1997). Essential oils produced from *Adansonia* species significantly reduced TAFs and AFB_1 secretion by *Aspergillus flavus* (47.2- 95.7%; 28.1- 89.7%) and *Aspergillus parasiticus* (42.7 - 93.3%; 25.9 - 80.2%) (El-Nagerabi *et al*., 2013). Furthermore, *Zataria multiflora* EO (at 150 mg/kg) significantly decreased AFs production (99.4%) (Gambori *et al*., 2009). Similar to the findings of El-Nagerabi *et al*. (2012), who looked at the effects of *Nigella sativa* EO on *A. flavus* and *A. parasiticus*, they found that the EOS showed great promise in lowering AFB_1 levels. At concentrations of 0.5 and 0.75 ml/l, respectively, essential oils of *Foeniculum vulgare, Cymbopogon martini*, and *Trachyspermum ammi* were reported to suppress the formation of different toxins by *A. niger* and *A. flavus* (Gemeda *et al*., 2014). Pandey *et al*. (2016) showed that *Lippia alba* EO suppressed AFB_1 synthesis in green gram. In addition, Sindhu *et al*. (2011) found that oil extracted from turmeric leaves inhibited AFs by 95.3% and 100%, and Prakash *et al*. (2011) found that EO extracted from *Ocimum gratissimum* inhibited AFs by a similar percentage.

Conclusion –

The growing population necessitates the accumulation of large quantities of healthy and safe food items particularly staple food item to be used in near future. However, improper storage of such food item leads to the invasion of mycotoxigenic fungi. As a result, food supplies become contaminated with multiple mycotoxins, which poses a global concern in relation to human health. Contamination of food crops and their resulting products particularly aflatoxins posses a significant danger to the lives of both humans and domestic animals. This issue is particularly critical in developing nations, where these toxin-infected products not only pose health risks but also cause decreased economic value in the worldwide food market. Various methods involving chemicals, physical alterations, and biological approaches were employed to reduce or entirely remove aflatoxins levels in food products to safe consumption thresholds. It is crucial that while decontaminating these products, their taste, smell, nutritional value, and the avoidance of creating harmful byproducts remain unaffected. The efficient removal of aflatoxins presents a significant challenge. Conversely, using synthetic chemicals to control aflatoxins-producing fungi raises substantial concerns, both from a human-made and environmental perspective. Therefore, employing environmentally friendly strategies such as plant extracts and essential oils for managing aflatoxins would be a safer option for both users and the environment. Hence, further investigation is necessary to establish uniform standards for the quality of natural extracts, assess their safety, determine the optimal timing of application, and ascertain the most effective concentrations suitable for various food commodities.

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Cite this article:

Avinash Jain and Shyam Govind Singh, 2023, “From field to forks: A deep dive into aflatoxin contamination in food items” ***Journal of Science Innovations and Nature of Earth***, Vol. 3(4), page-04-21

www.doi.org/10.59436/jsiane.com/archives3/4/105