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# WHAT MAKES RESEARCH ON AFLATOXIN CRUCIAL FOR HUMAN HEALTH AND DEVELOPMENT?

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**ABSTRACT**

Food security involves not only ensuring access to adequate food, but also ensuring that the food is nutritious and free from contaminants that can harm human health. Aflatoxins, produced by the fungi *Aspergillus flavus* and *A. parasiticus*, are one example of a contaminant that can pose a threat to food security. To address this issue, it is important to implement effective management practices throughout the food chain, from the field to the table, to minimize the risk of aflatoxin contamination. Additionally, promoting awareness about the dangers of aflatoxins at the social level and using a combination of genetic and management practices can help provide a stable and sustainable solution to this problem. This article extensively discusses the harmful effects of Aflatoxins (AFs) and outlines strategies for managing contamination before and after harvest, including the potential for breeding crops with higher resistance. The article also examines the relationship between moisture content and AF contamination in peanuts before harvest. It highlights the impact of AFs on the production of meat, milk, and eggs from animals and underscores the need for a comprehensive policy to prevent AF contamination from entering the food chain at every stage. Improved agronomic practices and cattle feeding, as well as public awareness efforts, can help reduce the risk of AFs in the food supply. With a combination of current genetic improvements and effective pre- and post-harvest management practices, it may be possible to mitigate the issue of AF contamination.

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## INTRODUCTION

Food security refers to the availability of an adequate, safe, and nutritious food supply that meets the dietary needs of the population at all times. Adequate food is a basic requirement for human survival and a balanced diet, containing carbohydrates, amino acids, vitamins, and minerals, is essential for a healthy and energetic life. Food insecurity is a major global challenge affecting approximately 700 million people, with 90% of these inhabitants residing in Africa and Asia (WHO, 2018). With the expected growth of the human population to 9.7 billion by 2050 (Thornton et al., 2011), the demand for food is expected to grow rapidly, and cereal production will need to increase by 60-100% by 2050 (Rayfus and Weisfelt, 2012; Thornton et al., 2011; Ahmed et al., 2013). Diseases in plants reduce the quantity and quality of food crops (Shuping and Ellof, 2017; Alam et al., 2017; Hamidou et al., 2022), and

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certain microbes can degenerate food safety (Massomo, 2020). The main genera of fungi that produce mycotoxins are *Aspergillus, Fusarium, Penicillium*, and *Alternaria* (Kumar et al., 2021; Shakoor et al., 2015; Ghuffar et al., 2018).

**Aflatoxins**

Aflatoxin is a toxic and carcinogenic substance produced by certain strains of the fungi *Aspergillus flavus*, *A. parasiticus* and *A*. *nomius* most common (Payne and Brown,1998) which are plentiful in hot and moist areas contaminate crops during harvest, and at storage. Toxic metabolites known as aflatoxin (AF) are produced by fungal species belonging to genus *Aspergillus* (Jeyaramraja et al., 2018). *A. flavus* is the most commonly found in agricultural fields, and when it invades crops like maize, peanuts, cotton, and tree nuts, it produces aflatoxins if the environmental conditions permit. It can contaminate crops such as corn, peanuts, and tree nuts, and is commonly found in developing countries with inadequate storage and agricultural practices. AF has been designated as oilseeds (groundnut, soybean, cotton and sunflower), cereals (maize, wheat, rice, sorghum and pearl millet), spices (black pepper, coriander, chilies, ginger and turmeric), nuts (Brazil nut, almond, walnut, coconut and pistachio), yam and some dairy products (Rajarajan et al., 2013). Aflatoxins pollute subsistence crops and pose a threat to vigor of consumer, and a substantial commercial load, cause 1/4$^{th}$ of the food crops to be demolished every year (WHO, 2018).

The problem of aflatoxin contamination (AC) in food crops, particularly groundnuts, has been a major concern in many countries, especially in Asia and Africa. The strict import standards set by developed countries have resulted in a ban on marketing of crops from these regions, affecting their economies. However, due to the lack of visible yield depression and immediate health effects, many growers are not aware of the harmful impact of AC on human health. It is essential to address the issue of AC in the entire food chain to ensure the production of safe and nutritious food, and to prevent health problems associated with aflatoxin exposure. Integrated aflatoxin management is crucial in reducing the impact of AC and promoting better health and financial outcomes.

Several fungi are free-living organisms that can easily find their way into crop products, especially when the weather conditions are favorable. Many of these fungi can survive without the host crops. Aflatoxins are toxic and carcinogenic chemicals produced by *A. flavus* and *A. parasiticus* (Figure 1 and Figure 2). Maize and groundnut are the most susceptible to aflatoxin contamination. The toxicity of aflatoxins is harmful as they are not destroyed at cooking temperatures and the body cannot change their chemical composition. Contaminated livestock and poultry feed produce contaminated milk, meat, and eggs.

**Characters of fungi producing aflatoxins**

Among the species that produce aflatoxin, the most important one is *Aspergillus flavus* (Klich, 2007). *A. flavus* is characterized with highly diverse genetically, several of varied vegetative resemblance clusters (Amaike and Keller, 2011) and variable types based on morphology, categorized into two types based on size of sclerotia, i.e., Group I (S strains) with sclerotia 400 μm in diameter (Cotty, 1989).

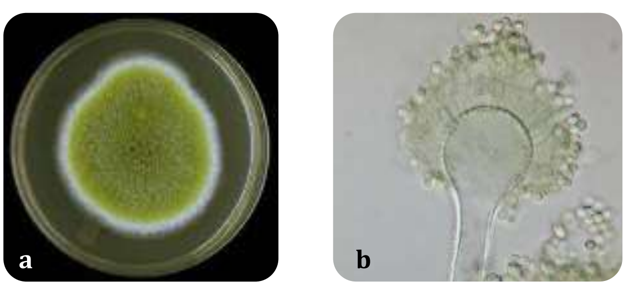


Figure 1: *Aspergillus flavus,* a) in petri dish; b) under microscope

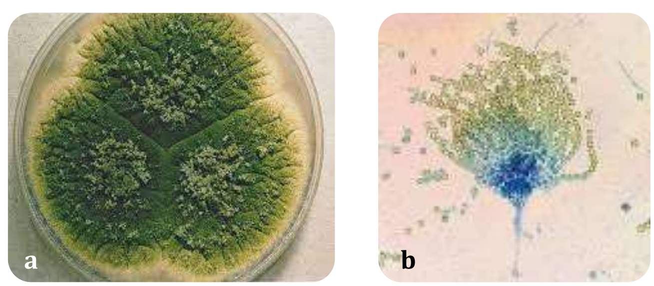


Figure 2: *Aspergillus parasiticus,* a) Colony growth on CYA medium; b) Conidia and conidiophores

Less variation in aflatoxin production is shown in S strains, conversely L strains are quite variable in the levels of aflatoxin produced and also include non-aflatoxigenic strains. S strains are generally higher aflatoxin producers than L strains and can produce aflatoxins G1 and G2 in addition to aflatoxins B1 and B2

(Cotty, 1997). *A. parasiticus* is another dominant aflatoxigenic species, able to produce all of the aflatoxins described above.

Host range and habitat is different in *Aspergillus flavus* and *A. parasiticus*. *Aspergillus flavus* prevails more commonly on cereals, oilseeds and dried fruits, as well as cash crops, such as groundnuts and corn (Abbas, 2002; Pandey et al., 2014; Shavkiev et al., 2022; Torres et al., 2014), while *A. parasiticus* is more firmly allied with soil atmosphere and infects underground plant parts (Horn et al., 2017). *A. flavus* produces B type AFs while *A. parasiticus* produces G AFs. (Bennett and Klich, 2003; Kumar et al., 2017).

**Types of aflatoxins**

Quadri et al. (2012) categorized AFs into six types: B1, B2, G1, G2, M1, and M2. In crops or their foodstuffs B1, B2, G1, G2 are found (AEFS. 2013), whereas M1 (Metabolite of B1) and M2 are found in the by-products of mammals for example dairy products (Lalah et al., 2020). AFs are very poisonous, primarily contaminate wide range of food commodities (Mutegi et al., 2009; Perrone et al., 2014; Iqbal et al., 2015). There are four major AFs viz. AFB1, AFB2, AFG1 and AFG2 among the twenty identified AFs (Pitt, 2000).

**Factors affecting production and contamination of aflatoxins**

Features that influence production and contamination of aflatoxins have been classified as chemical, physical, and biological. Chemical features consist of the application of fertilizers and/or fungicides. Physical features comprise ecological circumstances favorable to colonization of fungi and production of aflatoxins for instance relative moisture, temperature and insect infestation. Biological features interact between the toxigenic fungal species and substrate (D'Mello and Macdonald, 1977).

**How aflatoxins are injurious?**

Aflatoxin is harmful because it is a potent toxin and carcinogen. When ingested, it can cause a variety of health problems, including:

**Liver damage:** Aflatoxin is metabolized in the liver, where it can cause cell damage and potentially lead to liver cancer.

**Immune system suppression:** Aflatoxin can suppress the immune system, making individuals more susceptible to infections and diseases.

**Acute toxicity:** In high doses, aflatoxin can cause acute toxicity, leading to symptoms such as nausea, vomiting, and diarrhea.

**Carcinogenicity:** Aflatoxin is classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC), meaning it is a substance that has been determined to cause cancer in humans. Long-term exposure to aflatoxin can increase the risk of developing liver cancer.

Chronic exposure to aflatoxin, even in low doses, can have negative effects on human health and increase the risk of developing chronic diseases. It is also important to note that some people may be more susceptible to the effects of aflatoxin exposure, such as individuals with compromised immune systems, and should take extra precautions to reduce their exposure.

The contamination of food and feed with AFs can negatively impact the safety and value of these products, causing issues within the food chain (Figure 3). This contamination can put the safety, security, and nutrition of food at risk and affect a country's ability to trade (Ismaiel and Papenbrock, 2015). Although the contamination is usually not present in high levels, it can still have long-term effects if consumed regularly. AFs are widely found, toxic substances that can contaminate crops and pose a threat to the health of humans and livestock when ingested (Boutrif, 1998). The polyketide structure of AFs contains alternating carbonyl groups that have been linked to carcinogenic, immunosuppressive, and hepatotoxic effects, as well as physical and functional defects in human embryos or fetuses (Amaike and Keller 2011; Kensler et al., 2011). Consuming AF-contaminated food can have serious impacts on the liver (Gong et al., 2016; Kew, 2013). AFB1 is the most dangerous AF to humans and animals, as it is oncogenic and can cause liver cancer (IARC, 2012). This is why it is the most widely researched of all aflatoxins (Goto et al., 1996). Aflatoxicoses in humans and animals is caused by consuming large amounts of AF-contaminated food or feed in a single dose, or smaller amounts over a prolonged period (Williams et al., 2004). Benkerroum et al. (2020) classified aflatoxicoses based on severity, with acute cases leading to sudden death and chronic cases resulting in a gradual decline. Jaimez et al. (2000) found that the level of toxicity of AFs varies depending on the type, with AFs-B1 being the most toxic, followed by AFs-G1, AFs-B2, and AFs-G2.

AFs are steady substances that do not demolish by any normal culinary temperature (Mohsenzadeh et al., 2016; Kumar et al., 2017; Medina et al., 2017). The cells in living organisms are not able to abolish or relinquish AFs

(Brown, 2018). When animals fed contaminated feed (Fratamico et al., 2008), AFs pass into milk, eggs and meat (Iqbal et al., 2014). Aflatoxin is one of the most significant limitation restraining production of quality seed (Nigam et al., 2009). AC in groundnut seeds, is preventive in international trade (Wagacha and Muthomi, 2008).

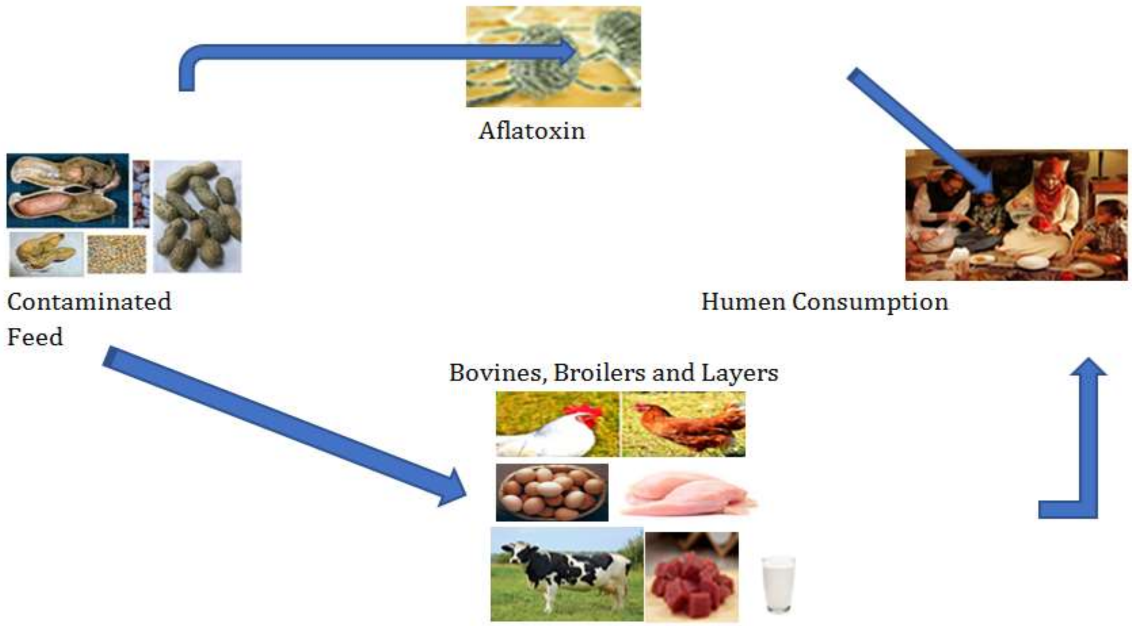


Figure 3: How aflatoxin become component of food chain.

Regardless of key adverse effects of aflatoxins, those are obviously underrated in the developing countries. The toxins cannot be realized or sniffed; growers and customers characteristically do not understand what aflatoxins are, the problems they cause, or plan to alleviate them; detection entails tests in research laboratory, not available easily (Udomkun et al., 2017). It is crucial to control AC in order to ensure food security (Wu and Khlangwiset, 2010). Aflatoxins can infect peanuts both in the field and during storage, from harvesting to post-harvesting. To reduce the risk of food security and produce high-quality food, it is necessary to implement measures to control contamination during all stages, including pre-harvesting, post-harvesting, and storage. The green fungal colony of *A. flavus* can thrive under various stressful conditions, such as heat stress and moisture during shell growth, and can infect seeds through wounds caused by nematodes and insects or other injuries during the growing process (Mehan et al., 1991; Jeyaramraja et al. 2018). Proper crop management at pre- and post-harvest times can significantly reduce aflatoxin contamination (Hesseltine, 1974).

**Management of aflatoxins**

It is important to reduce exposure to aflatoxin, especially for populations in developing countries where food contamination is common and regulations may be less stringent. To reduce the risk of aflatoxin exposure

1) Aflatoxin contamination can be reduced by various agronomic practices during pre-harvest and post-harvest.

2) Adding nontoxigenic strains of *A. flavus* to soil before sowing has been effective in reducing the population of toxic *Aspergillus* spp.

3) There is genetic diversity in groundnut against *A. flavus*, but this data have not yet been successfully used to develop resistant cultivars. Developing resistant cultivars may prove to be the best strategy to effectively control aflatoxin contamination.

It is important to properly store food products and to follow good agricultural practices. The implementation of good agronomic practices (GAPs), good manufacturing practices (GMPs) and good storage practices (GSPs) during pre- and postharvest phase can moderate AFs' contamination of crops to an optimistic level (Kamle et al., 2019). To switch AFs in food chains and enhance productivity of crops, many procedures and strategies are existing that can be applied during pre- and post-harvest phase. -At present, relying upon single plan is not applied style to solve this problem. Combination of two or more management strategies from the field up to feed processing or table is essential to alleviate the effects attributed to aflatoxins. This review summarizes the progress in vindicating the effect of aflatoxins in groundnuts cultivating regions.

**Pre-Harvest strategies to reduce aflatoxin contamination**

More than a few factors regulate growing of fungi and AC in crops: few are environmental whereas others are associated with crop management. Ecological circumstances are normally beyond control; nevertheless, adaptating agronomic practices in crop production may ensure reduced fungal infection, growth and production of aflatoxin. These tactics alleviate infection by fungi during preharvest stage. Provision crops with the excellent conceivable growing situation, it becomes effective to diminish injury by pests, drought and later by fungi.

**Good agricultural practices**

Agronomic practices that consist of insect and disease management in field crops, crop rotation and suitable irrigation, usage of superior seed, and changing the time of sowing and harvesting have had some effect on the control of AC (Bhatnagar et al., 1994). Dry conditions near harvesting commonly makes shells liable to cracking that facilitates entering aflatoxigenic fungi. Sowing crop earlier is helping to avoid it. Eradication of weed hold soil moisture critical for plant growth and avoidance drought that disposes developing shells to crack. Keeping good agricultural practices that endorse the vigor of crops can decrease but not eradicate AC during preharvest, e.g.-, insect resistant germplasm. For instance corn renovated with the Bt maize, has decreased the degree of pest injury generally related with amplified contamination of mycotoxin. Controlling the growth of termite predominantly as the crop matures, prevent damage to pods by aflatoxigenic fungi. Lack of moisture when the crop is at emerging stage is an auspicious to fungal infection succeeding AC. Tied ridges improve penetration of water thus diminishing interaction of the crop to *A. flavus* infestation. Tied ridges should be put in place primarily in the cropping season to detention rainfall of water and ensure moisture necessary near maturity. Mulching is also supportive to preserve moisture (ICRISAT, 2016). Watering of groundnuts avoids AC of this crop, possibly by avoiding the drought stress recognized to encourage AC in groundnuts. Ijaz et al. (2022) reported adding soil amendments (Farmyard manure, gypsum and cereal crop residue) significantly mitigated AC as compared to control however, various treatments performed equal in reducing AC quantified with ELISA. Soil amendments not only resulted in decreased contamination of AF but enhanced the yield as compared to control as well. So, it is recommended to add at least any one soil amendments to reduce AC- . Pods well-developed are not penetrated by insects and this decreases the the chance of entrance of fungi in the seed. Calcium is the most important elements in the development of pods of groundnut (Jain et al., 2011). Gypsum (Calcium-containing soil amendments) curtails pre-harvest AC in groundnuts (Waliyar et al., 2013; Gebreselassie et al., 2014; Ijaz et al., 2021). Bairagi et al., (2017) advocates adding gypsum @ 250 Kg hectare$^{-1}$ causes significant improvement in yield. Nevertheless, optimization of management practices to control aflatoxin contamination is not permanently conceivable because of production cost, terrestrial site, and the nature of the crop production system. Hence, there is a crucial prerequisite to advance and participate supplementary easy-to-operate approaches to manage AC during preharvest.

**Mitigation of aflatoxin infection during harvesting**

Immature kernels have high succulence contents that support fungal infection and growth leading to AC. Hence, harvesting when the crop is full matured restrict the contact of the produce to high temperature, unpredicted precipitation or drought, which excite infection, thus reducing perspective of AC at pre harvest. Damage to pods can be prevented by careful digging. To gain kernels undamaged, appropriate harvesting confirms that digging focused mainly at rooting zone. Removal of all the soil attached to the pods in collection is helpful in avoidance of carrying the fungus into stores (ICRISAT, 2016).

**Post-Harvest strategies to reduce aflatoxin contamination**

It is believed that there is a higher likelihood of AC after harvest (Wild and Hall, 2000). Poor management practices and unfavorable weather conditions during and after harvest contribute to this risk. Mold growth and significant grain degradation in storage facilities, resulting from inadequate storage, also contribute to the issue. To effectively manage post-harvest aflatoxin, Waliyar et al. (2015) proposed practical tactics that can be implemented by farmers and traders.

1. To minimize the risk of aflatoxin contamination, one of the tactics is to reduce moisture content to no more than 8% during storage.
2. Another approach to manage post-harvest aflatoxin is to use pesticides to prevent insect infestations and fungal infections during storage.
3. Grading and sorting of produce as a way to manage post-harvest aflatoxin contamination.
4. In addition, re-drying of groundnut shells and seeds after grading as another way to manage post-harvest aflatoxin.
5. Appropriate storage as a means to prevent mold growth and manage post-harvest aflatoxin is necessary.
6. Avoiding re-humidification of shells as another way to manage post-harvest aflatoxin.
7. Waliyar et al. (2015) emphasized the urgency to research and develop techniques for detoxifying contaminated products.
8. Raising awareness among smallholders about existing knowledge and understanding of AC as a way to effectively manage it.

Waliyar et al. (2015) advised that a combination of sustainable and profitable methods would be more effective in managing post-harvest AC than relying solely on one or two solutions.

**The application of biocontrol agents as a way to manage aflatoxins**

According to Horn et al. (1995) and Horn and Dorner (1998), the major source of *A. flavus* infection in groundnut kernels is the groundnut shell that matures underground. To control aflatoxins, pre-harvest application of biocontrol agents, such as antagonistic organisms, is an important tactic. Ehrlich (2014) found that factors such as pH, soil type, and availability of water, carbon, nitrogen, and minerals play a role in a fungus's ability to compete with related strains. In vitro studies have shown that growth of the fungus and formation of aflatoxins by *Aspergillus* species can be controlled by biocontrol agents, but their efficacy in the field has not been confirmed (Dorner, 2004). Some yeast species have been shown to significantly retard growth of *Aspergillus in vitro*, but further field trials are needed to determine their effectiveness in reducing aflatoxin contamination (Yin et al., 2008). The application of *A. flavus* strains that do not produce toxin to groundnut fields has been shown to effectively reduce aflatoxin contamination by toxin-producing strains (Yan et al., 2021). The genetic differentiation of *A. flavus* populations is independent of geographic distance and can be useful in developing a suitable biocontrol management strategy (Acur et al., 2020). According to Yin et al. (2008), the ability of a fungus to compete with closely related strains depends on various factors, and these need to be considered in order to successfully achieve the target.

1. Nontoxigenic strains capable of occupying the same habitats as toxigenic strains have the ability to compete and displace them, as demonstrated by Cotty et al. (2007).
2. In order to achieve the goal of successful exclusion, the nontoxigenic strains must predominate in agricultural settings when crops are susceptible to infection by toxigenic strains. The factors that determine the effectiveness of this approach have been studied by Undumkon et al. (2017).
3. The development of biocontrol strains requires careful consideration of the production and distribution capacity of conidiospores that are more effective than toxic strains in soil.
4. Use at the proper moment.

It is not possible to completely eliminate a fungal infection causing *A. flavus* (AC) through postharvest processes once it has taken hold (Nigam et al., 2009). While proper postharvest techniques can help minimize AC, they are not effective if the fungus is already present in the kernels prior to drying and storage. Additionally, the small-scale farmers in developing countries, who account for approximately 60% of the world's groundnut production, do not widely adopt these practices (Upadhyaya et al., 2002). A more practical approach to combat AC is to identify sources of resistance to the causing fungus and use resistant cultivars.

**Breeding groundnut for resistance against aflatoxin contamination**

The first documentation of genetic diversity in groundnuts and its impact on aflatoxin production dates back to the 1960s (Rao and Tulpule, 1967). Mixon and Roger (1973) were pioneers in the application of genetics in managing aflatoxin. A classification of groundnut germplasm into susceptible and resistant groups was done using a technique that involved rehydrating groundnut seeds in vitro with aflatoxigenic fungi. Based on the data from *in vitro* seed colonization

(IVSC), genotypes of groundnuts from the Valencia group were found to have substantial resistance to *A. flavus* and *A. parasiticus*.

Three mechanisms of resistance against fungi producing aflatoxin have been identified, including:

1. *In vitro* seed colonization resistance (IVSC).
2. Resistance to pre-harvest aflatoxin contamination (PAC).
3. Resistance to aflatoxin production in groundnut seeds has been documented.

However, the aflatoxin is only produced in the cotyledons of groundnut kernels after fungal infection (Liang et al., 2006). Various researchers have identified sources of resistance to these mechanisms (Waliyar et al., 2016; Upadhyaya et al., 2002; Anderson et al., 1995; Mehan et al., 1989). The research conducted by Nayak et al., (2017), identified the genes involved in the host-pathogen interaction and markers that can be used to improve varieties.

Non-genetic factors such as the density of microbes in the soil, population diversity, and the effect of aquatic stress, play a role in resistance to *A. flavus* infection and aflatoxin production. Despite this, extensive phenotyping of germplasm has identified many entries with low infection and aflatoxin production, and this selected material is now being used for breeding aflatoxin-resistant genotypes (Cotty and Jaime-Garcia, 2007; Pandey et al., 2016). However, the trait of aflatoxin resistance is highly influenced by environmental conditions, making breeding for this trait challenging. Genotypes that are tolerant to drought have been found to be resistant to aflatoxin, so screening for drought tolerance is a useful tool to identify indirect sources of resistance (Holbrook et al., 2009). The mechanism behind the inheritance of aflatoxin resistance is not clear, and it is important to generate consistent data using molecular markers that can be used to develop long-lasting resistant genotypes. Advances in mycological expressed sequence tags, microarrays, and genome sequencing have resulted in the identification of several genes involved in host-pathogen interactions. Additionally, projects aimed at identifying genes coding for antimycotic compounds, resistance-related proteins, and QTLs associated with aflatoxin resistance are ongoing (Jeyaramraja et al., 2018).

Studies conducted in the 1990s and early 2000s showed that resistance to aflatoxin production in groundnut has low to moderate broad sense heritability and combining ability of resistance sources. Three resistance mechanisms were identified by Utomo et al. (1990) but it was found that different genes control these mechanisms and there was no significant association among them. Later, Upadhyaya et al. (2002) confirmed these findings. Xue (2004) reported largely non-additive genetic variance for aflatoxin production, suggesting that selection for this trait in early generations would not be effective. However, the genetics of resistance mechanisms have not been established. Additionally, the allelic association among multiple sources for each resistance mechanism needs to be understood to improve breeding approaches for resistance to aflatoxin. Groundnut has genetic diversity for various resistance mechanisms, but no genotype has all these mechanisms to effectively deal with aflatoxin challenge. Thus, more precise phenotyping and diverse genetic populations along with various "omics" techniques are required to identify genomic regions and candidate genes for improved breeding. Genetic resistance will provide protection from infection in the field and post-harvest management will reduce aflatoxin levels in the produce.

Resistance to *Aspergillus* spp. in groundnut is associated with the production of resveratrol, a natural phytoalexin produced by developing seeds. Varieties with resistance display enhanced defense with increased production of resveratrol upon infection. The host's defense mechanism involves oxidative balance in response to reactive oxygen species (ROS) produced in response to *Aspergillus* infection. A variety of genes are involved in this process, as evidenced by the expression of a wide range of genes (Nayak et al., 2017).

## CONCLUSION

Research on aflatoxins is beneficial for the human population in several ways

### Improving food safety

Aflatoxins are toxic substances produced by fungi that can contaminate crops such as peanuts, maize, and other staple foods. Research on aflatoxins helps to identify ways to prevent and control contamination, ensuring the safety of the food supply and protecting the health of the population.

### Reducing food insecurity

Aflatoxin contamination can reduce the quantity and quality of crops, leading to food insecurity in affected regions. Research on aflatoxins can provide solutions for controlling contamination and improving crop yields, reducing the risk of food insecurity.

**Protecting Public Health**

Aflatoxins can cause serious health problems such as liver cancer, stunted growth, and weakened immune systems. Research on aflatoxins can help to prevent exposure and minimize the risk of disease.

**Improving agricultural practices**

Research on aflatoxins can provide valuable information on the most effective agronomic practices for reducing contamination, improving crop yields, and reducing the risk of food insecurity.

Overall, research on aflatoxins is essential for ensuring food safety and improving the health and well-being of the human population.

There are several steps that can be taken to reduce the effects of aflatoxin:

**Proper food storage**

Store food products in a dry, cool place to reduce fungal growth and aflatoxin production.

**Adequate drying of crops**

Properly dry crops to reduce moisture levels and prevent fungal growth.

**Good agricultural practices**

Implement good agricultural practices such as rotating crops, using disease-resistant seed varieties, and applying fungicides to reduce fungal contamination.

**Inspection and testing**

Regularly inspect and test food products for aflatoxin contamination, especially in countries where contamination is common.

**Awareness and education**

Increase awareness and education among farmers, food processors, and consumers about the dangers of aflatoxin and how to reduce exposure.

## AUTHORS' CONTRIBUTION

AA developed the research question for the review article, identifying the research gap that the article aims to address, SA synthesized the findings of the reviewed studies and identified gaps in the literature, SS screened the literature based on their title, abstract, and full text, as appropriate, to determine their relevance to the research question and eligibility for inclusion in the review, RM skillfully criticized the component of identifying sources of resistance against aflatoxin contamination and her feedback improved the quality of the article, MK synthesized information from a range of sources, including scientific studies and reports, to support her argument for the use of soil amendments in achieving food safety targets, JI has the knowledge, expertise, and aptitude in Plant breeding and Genetics and provided valuable feedback to improve the quality of article, UJ and QS thoroughly reviewed the manuscript and provided useful feedback that helped improve the article.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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