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Systematic review on Aflatoxin contamination in Ethiopia: current status and implications

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Abstract

Aflatoxin contamination poses significant threats to public health and economic stability, particularly in regions like Ethiopia, where agricultural practices are central to livelihoods. This review provides a snapshot of the current status of Aflatoxin contamination globally, with a focus on Ethiopia. Aflatoxin contamination is a global concern, affecting both developed and developing countries. In Africa, where climatic conditions favor the growth of Aflatoxin-producing fungi, the problem is particularly acute. Ethiopia, as one of Africa's largest agricultural producers, faces significant challenges in mitigating Aflatoxin contamination. Major sources of Aflatoxin in Ethiopia include groundnuts, maize, and other staple crops, with inadequate storage facilities and poor agricultural practices exacerbating the issue. Several African countries, including Ethiopia, experience adverse effects on public health due to Aflatoxin exposure, ranging from acute toxicity to chronic health problems such as liver cancer. Furthermore, Aflatoxin contamination imposes substantial economic burdens, including reduced agricultural productivity, trade restrictions, and increased healthcare costs. Mitigation strategies for Aflatoxin contamination in Ethiopia and other affected regions encompass a multifaceted approach, including improved agricultural practices, proper drying and storage techniques, and the development and implementation of regulatory measures and quality control standards. Additionally, promoting crop diversification and investing in research and technology for Aflatoxin detection and management are crucial components of effective mitigation strategies. In conclusion, Aflatoxin contamination in Ethiopia and Africa remains a pressing issue with far-reaching implications for public health and economic development.

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Introduction

Aflatoxin contamination, caused by molds like *Aspergillus flavus* and *A. parasiticus*, poses a significant threat to food safety and public health worldwide, with particularly severe impacts in countries like Ethiopia, where it affects both the economy and the sustenance of the population due to its potent carcinogenic properties[1]. Also, Aflatoxins are potent carcinogens produced by molds like *Aspergillus flavus* and *A. parasiticus*, commonly infecting crops such as maize and peanuts[2]. Contamination of staple foods like maize and peanuts has significant health and economic impacts, particularly in warm, humid regions where mold growth thrives[3]. Africa bears a significant burden of Aflatoxin contamination due to its climate, agricultural practices, and inadequate food storage facilities[4]. Crops such as maize, wheat, barley, and cassava can be harmful due to toxins like Aflatoxins, cyanogenic glycosides, and solanine, which pose serious health risks if not properly handled or processed, with Ethiopia being particularly vulnerable to Aflatoxin contamination in staple crops like maize and peanuts[5]. In Ethiopia, Aflatoxin contamination mainly arises from poor post-harvest handling, inadequate storage, and limited awareness among farmers and food processors[6]. Factors such as high temperatures, humidity, and improper drying and storage exacerbate the risk of Aflatoxin contamination in staple crops[7]. Many African countries, including Ethiopia, struggle to combat Aflatoxin contamination due to ideal conditions for mold growth created by high temperatures and humidity, inadequate agricultural practices and storage methods, and challenges such as limited detection technology, insufficient regulatory frameworks, and heavy reliance on agriculture[8]. Other affected nations in Africa include Kenya, Nigeria, Tanzania, and Uganda, among others[9]. In Ethiopia, Aflatoxin contamination threatens food security and public health, impacting both rural and urban populations[10]. Consuming Aflatoxin-contaminated foods can cause liver cancer, immune suppression, and stunted growth in children[11]. Chronic exposure to Aflatoxins can lead to long-term health complications and increased healthcare costs[12]. Aflatoxin contamination also harms the economy by reducing agricultural productivity, causing trade restrictions, and resulting in revenue losses from rejected exports[13]. The economic burden extends beyond agriculture, affecting healthcare costs, livelihoods, and consumer confidence in domestic foods[14]. Comprehensive mitigation strategies, including promoting proper drying, storage, and handling of crops, are essential to address Aflatoxin contamination in Ethiopia and other affected regions[15]. Research should focus on breeding crops resistant to Aflatoxin-producing fungi to reduce contamination risk[16]. Strengthening food safety regulations and enforcement mechanisms can ensure compliance with Aflatoxin limits in food products, safeguarding public health and facilitating trade[17]. Raising awareness about Aflatoxin risks and prevention is crucial for encouraging best practices[18]. Investing in storage

infrastructure and Aflatoxin detection technologies can reduce contamination risks along the food supply chain[19]. Hence, this review aimed to assess the current status of Aflatoxin contamination in Ethiopia, its sources, and mitigation strategies.

Review methodology

To facilitate a comprehensive and efficient literature search for the systematic review on Aflatoxin contamination in Ethiopia, several key index terms were employed. These included 'Aflatoxin', which encompassed related terms such as 'Mycotoxins' and specific types like 'Aflatoxin B1' and 'Aflatoxin M1', critical for identifying relevant studies on the contaminants themselves. The term 'Contamination' was also used to capture studies related to 'Mycotoxin contamination', 'Agricultural contamination', 'Food contamination', and 'Environmental contamination'. To narrow the focus to the regional context, 'Ethiopia' and related terms like 'Ethiopian agriculture' and 'Ethiopian food safety' were included. For exploring health impacts, 'Health Implications' terms were utilized, addressing the 'Health effects of Aflatoxins', 'Toxicity', 'Carcinogenicity', and 'Liver disease' associated with exposure. The term 'Prevalence and Occurrence' helped to identify studies on 'Aflatoxin levels', 'Occurrence of Aflatoxins', and 'Prevalence in crops'. Additionally, 'Mitigation and Management' strategies were explored, including 'Aflatoxin control', 'Mitigation strategies', 'Food safety measures', and 'Agricultural practices'. 'Regulation and Policy' terms like 'Food safety regulations', 'Policy interventions', and 'National guidelines' were also explored. To ensure a thorough and rigorous review process, methodological terms were also used such as 'Systematic review', 'Literature review', 'Data extraction', and 'Quality assessment'. Finally, 'Search Strategies' including 'Search methodology', 'Database search', and 'Keyword search' were focussed on, and 'Data Synthesis' methods such as 'Qualitative synthesis', 'Meta-analysis', and 'Data analysis' were employed to effectively summarize and interpret the findings.

Current status of Aflatoxin contamination

Aflatoxins, difuranocoumarin derivatives produced by *Aspergillus* species such as *A. flavus* and *A. parasiticus*, include the highly toxic Aflatoxin B1($C_{17}H_{12}O_6$) and are a global concern, especially in hot, humid regions[20]. Contamination levels vary by year and region due to factors like weather and storage, but efforts to mitigate Aflatoxin include improving agricultural practices, enhancing storage, and rigorous testing[21]. Aflatoxin levels in Ethiopia vary due to practices, climate, and storage conditions, so for the latest data, consult Food and Agriculture Organization (FAO), World Health Organization (WHO), and local reports, while international organizations like FAO and WHO collaborate globally to raise awareness, develop regulations, and provide technical assistance to address Aflatoxin contamination and its effects on public health and food security[22]. Aflatoxin contamination has been a persistent issue in Africa, particularly in regions with warm and humid climates where crops such as maize, peanuts, and tree nuts are commonly grown[23]. Aflatoxin contamination, which leads to severe health issues and billions in economic losses, affects agriculture and public health, with Africa focusing on improving practices and storage[24]. In Ethiopia, where Aflatoxin contamination is a major concern in maize and groundnuts, initiatives focus on raising awareness among farmers, traders, processors, and consumers about the risks and prevention measures[5]. Efforts to address Aflatoxin contamination in Ethiopia includes better agricultural practices, improved storage, and increased awareness[25]. Groundnuts and maize are among the most affected crops, with contamination levels exceeding regulatory limits in many instances[26]. The FAO and WHO combat Aflatoxin contamination by enforcing food safety standards, promoting good agricultural practices, supporting research, and improving local testing capacities, with recommended measures including proper storage, regular testing, and education to protect public health and enhance food safety globally and in Ethiopia.

Major sources of Aflatoxin in Ethiopia

In Ethiopia, Aflatoxin contamination mainly originates from crops, storage practices, feed, and environmental factors, commonly affecting maize, peanuts, cottonseed, and tree nuts (Table 1). Poor storage conditions, inadequate drying, and improper handling practices contribute to the growth of *Aspergillus* fungi, which produce Aflatoxins[27]. Improper storage in warm, humid conditions can lead to fungal growth and Aflatoxin production, with traditional methods, often inadequate for prevention[28]. Inadequate processing methods, such as milling and shelling, can spread Aflatoxin contamination throughout food products[29]. Additionally, processing facilities with poor hygiene standards may contribute to Aflatoxin contamination[30]. Contaminated crops, such as maize and peanuts, used in livestock feed can lead to Aflatoxin buildup in animal products like milk, meat, and eggs[31]. Ethiopia's warm and humid climate provides favorable conditions for the growth of *Aspergillus* fungi, the primary Aflatoxin producers[5]. Climate change may worsen Aflatoxin contamination in crops, so improving agricultural practices, upgrading storage, enhancing processing methods, and raising awareness about the risks is essential.

Countries affected by Aflatoxin in Africa

Several African nations, including Ethiopia, Ghana, Kenya, Malawi, Mozambique, Nigeria, Senegal, Tanzania, Uganda, and Zambia have faced Aflatoxin contamination[17]. These

Table 1. The major sources and occurrence of Aflatoxin in different agricultural crops.

Foodstuffs	Mean Aflatoxin concentrations	Acceptable level of Aflatoxin	Ref.
Maize	864.66 μg·kg^{-1}	20 ppb	[32]
Wheat	1.405 ng·g^{-1}	3.14 μg·kg^{-1}	[33]
Soybeans	4 μg·kg^{-1}	20 μg·kg^{-1}	[34]
Tree nuts	15 μg·kg^{-1}	8 or 10 μg·kg^{-1}	[35]
Copra	< 20 ppb	4 μg·kg^{-1}	[36]
Cottonseed	20 ng·g^{-1}	20 μg·kg^{-1}	[37]
Groundnuts	61 μg·kg^{-1}	20 mg·kg^{-1}	[33]
Spices	5 μg·kg^{-1}	30 μg·kg^{-1}	[38]
Animal feeds	20 ppb	20 ppb	[39]
Animal products	60%–80%	50 and 80 ppm	[40]

Sources: Own data collection and simplification.

countries struggle with Aflatoxin contamination due to inadequate storage, poor agricultural practices, and limited resources, especially in Ethiopia, where maize and groundnuts are staple crops[5]. Aflatoxin contamination affects multiple regions in Ethiopia, with heavy impacts in maize-producing areas of Eastern Ethiopia and maize and groundnut zones of Southern Ethiopia[41]. Similarly, in Central Ethiopia (Amhara), maize-producing areas are also at risk of Aflatoxin contamination[42]. Aflatoxin contamination in cereals, nuts, and seeds poses serious health risks to humans and animals if consumed in high levels[43].

Impacts of Aflatoxin contamination on public health and economy

Public health impacts

Aflatoxins, especially Aflatoxin B1, are potent carcinogens classified as Group 1 by the International Agency for Research on Cancer (IARC)[44]. Prolonged exposure to Aflatoxins in contaminated food can cause various cancers, especially liver cancer[45]. Aflatoxin exposure, primarily from contaminated food contributes significantly to global health issues by causing an estimated 25,000 to 155,000 liver cancer cases annually, with a notable impact in Ethiopia, and can also lead to acute toxicity with symptoms such as vomiting, abdominal pain, convulsions, and potentially death[46]. Chronic Aflatoxin exposure can weaken the immune system, increase susceptibility to infections, and cause stunted growth and developmental delays in children[47].

Economic impacts

Aflatoxin contamination causes food losses, scarcity, waste, and undermines food security and economic productivity[10]. Aflatoxin-related issues can reduce export revenues and impose significant healthcare costs for diagnosis, treatment, and care for cancer and other complications[48]. Aflatoxin contamination can devastate the livelihoods of farmers and food producers, especially in developing countries where agriculture is a major economic sector[49]. Farmers dealing with Aflatoxin contamination faces severe health risks and economic losses as affected crops may be unmarketable or fetch lower prices, leading to reduced incomes and food insecurity, compounded by inadequate storage, ineffective control measures, and limited handling knowledge[50]. Thus, addressing Aflatoxin contamination demands a comprehensive strategy including prevention, detection, regulation, and innovation to mitigate its public health and economic impacts.

Mitigation strategies of Aflatoxin contamination

Efforts to mitigate Aflatoxin contamination in Ethiopia include pre-harvest, harvest, and post-harvest interventions, such as promoting good agricultural practices like crop rotation, pest management, and irrigation[15]. Post-harvest interventions focus on improving storage facilities, implementing proper drying techniques, and utilizing Aflatoxin-detoxifying agents[51] (Table 2). Raising awareness about Aflatoxin risks and implementing testing and certification protocols is crucial for ensuring food safety and market access.

Implementing these strategies can significantly reduce Aflatoxin contamination in the food supply chain. Positive results include improved public health, enhanced trade opportunities due to compliance with safety standards, and increased crop yields from resistant varieties. Additionally, raising awareness and improving infrastructure can lead to widespread adoption of best practices, further minimizing contamination. However, negative aspects include the high initial costs of research, infrastructure development, and technology implementation, as well as potential resistance from stakeholders resistant to change. Effective implementation of these strategies could prevent up to 90% of Aflatoxin contamination, although actual results may vary based on region-specific factors and the extent of adoption.

Gaps and future lines of work

Although some studies on Aflatoxin contamination in Ethiopia exist, comprehensive nationwide data is lacking. Extensive surveys covering various regions, crops, and storage conditions are needed. While current research focuses on staple crops like maize, peanuts, and cereals, more studies are required for other commonly consumed crops such as millet, sorghum, and spices. Understanding the economic, health, and social impacts, including food security and trade restrictions, is crucial. Additionally, limited research on environmental factors like climate variability and soil conditions exists. Further investigation is needed to assess the effectiveness of existing mitigation strategies and regulatory frameworks. Establishing a nationwide surveillance program and developing integrated crop management strategies are essential steps. Climate-resilient agricultural practices and public health interventions are also necessary. Capacity-building initiatives and multi-stakeholder collaborations can enhance Aflatoxin management. Advocating for policy reforms will strengthen regulatory enforcement and ensure compliance. Addressing these gaps will enhance Ethiopia's capacity to mitigate Aflatoxin contamination effectively, protecting public health and agricultural productivity.

Table 2. Some of the intervention strategies of Aflatoxin contamination.

No.	Intervention strategies	Elemental description	Ref.
1	Improved agricultural practices	Proper agricultural practices like effective drying, storage, and handling of crops can reduce Aflatoxin contamination pre- and post-harvest.	[52]
2	Adoption of Aflatoxin-resistant varieties	Research should focus on breeding crops resistant to Aflatoxin-producing fungi to reduce contamination.	[53]
3	Enhanced food safety regulations	Enhancing food safety rules and enforcement ensures adherence to Aflatoxin limits, protecting public health and boosting trade.	[54]
4	Education and awareness campaigns	Raising awareness about Aflatoxin risks and prevention among all stakeholders is crucial for adopting best practices.	[55]
5	Investment in infrastructure	Investing in detection and monitoring infrastructure and technology can reduce Aflatoxin contamination risks in the food supply chain.	[56]

Summary and conclusions

Aflatoxin contamination is a pressing issue globally, with Africa and Ethiopia facing significant challenges. In Ethiopia, groundnuts, maize, and other staple crops are major sources of Aflatoxin. Several African countries, including Ethiopia, suffer from its effects, impacting public health and the economy. Aflatoxin exposure can lead to health problems like liver cancer and economic losses due to reduced crop yields and trade restrictions. Mitigation strategies include improved agricultural practices, post-harvest management, and regulatory measures. Aflatoxin contamination is a complex challenge in Ethiopia and Africa, affecting both health and the economy. Comprehensive efforts involving stakeholders at all levels are crucial for mitigation. Stringent regulations, awareness campaigns, and research are necessary to address this issue effectively. Collaboration among African nations and international organizations is vital for sustainable solutions.

Author contributions

The author confirms the sole responsibility for all aspects to this study.

Data availability

Data sharing is not applicable to this article as no new data were analyzed in this study.

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Conflict of interest

The author declares that there is no conflict of interest.

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References

1. Ncube J, Maphosa M. 2020. Current state of knowledge on groundnut aflatoxins and their management from a plant breeding perspective: lessons for Africa. *Scientific African* 7:e00264
2. Kumar A, Pathak H, Bhadauria S, Sudan J. 2021. Aflatoxin contamination in food crops: causes, detection, and management: a review. *Food Production, Processing and Nutrition* 3:17
3. Dövényi-Nagy T, Rácz C, Molnár K, Bakó K, Szláma Z, et al. 2020. Pre-harvest modelling and mitigation of aflatoxins in maize in a changing climatic environment — A review. *Toxins* 12:768
4. Keyser JC, Sela S. 2020. *Innovations in Food Trade: Rethinking Aflatoxin Management in East Africa*. Washington DC, USA: The World Bank. https://documents1.worldbank.org/curated/en/278421605883762320/pdf/Innovations-in-Food-Trade-Rethinking-Aflatoxin-Management-in-East-Africa.pdf
5. Guchi E. 2015. Aflatoxin contamination in groundnut (*Arachis hypogaea* L.) caused by *Aspergillus* species in Ethiopia. *Journal of Applied & Environmental Microbiology* 3:11–19
6. Cervini C, Verheecke-Vaessen C, He T, Mohammed A, Magan N, et al. 2022. Improvements within the peanut production chain to minimize aflatoxins contamination: an Ethiopian case study. *Food Control* 136:108622
7. Demissie N. 2018. A review of aflatoxin: occurrence, prevention, and gaps in both food and feed safety. *Novel Techniques in Nutrition & Food Science* 1:35–43
8. Sowley ENK. 2016. Aflatoxins: A silent threat in developing countries. *African Journal of Biotechnology* 15:1864–70
9. Kimanya ME. 2015. The health impacts of mycotoxins in the eastern Africa region. *Current Opinion in Food Science* 6:7–11
10. Unnevehr L, Grace D. 2013. *Aflatoxins: Finding solutions for improved food safety*. Intl Food Policy Res Inst. vol. 20. Unnevehr, Laurian, Grace, Delia. 60 pp
11. Ogodo AC, Ugbogu OC. 2016. Public health significance of aflatoxin in food industry—A review. *European Journal of Clinical and Biomedical Sciences* 2:51–58
12. Ismail A, Naeem I, Gong YY, Routledge MN, Akhtar S, et al. 2021. Early life exposure to dietary aflatoxins, health impact and control perspectives: a review. *Trends in Food Science & Technology* 112:212–24
13. Coulibaly O, Hell K, Bandyopadhyay R, Hounkponou S, Leslie JF. 2008. Economic impact of aflatoxin contamination in sub-Saharan Africa. *Mycotoxins: detection methods, management, public health and agricultural trade*. UK: CABI. pp. 67–76. doi: 10.1079/9781845930820.0067
14. Jaffee S, Henson S, Unnevehr L, Grace D, Cassou E. 2018. *The safe food imperative: Accelerating progress in low- and middle-income countries*. Agriculture and Food Series. Washington, DC, USA: World Bank. 208 pp. doi: 10.1596/978-1-4648-1345-0
15. Parimi V, Kotamraju VKK, Sudini HK. 2018. On-farm demonstrations with a set of good agricultural practices (GAPs) proved cost-effective in reducing pre-harvest aflatoxin contamination in groundnut. *Agronomy* 8:10
16. Bhatnagar-Mathur P, Sunkara S, Bhatnagar-Panwar M, Waliyar F, Sharma KK. 2015. Biotechnological advances for combating *Aspergillus flavus* and aflatoxin contamination in crops. *Plant Science* 234:119–32
17. Chilaka CA, Obidiegwu JE, Chilaka AC, Atanda OO, Mally A. 2022. Mycotoxin regulatory status in Africa: a decade of weak institutional efforts. *Toxins* 14:442
18. Kaale LD, Kimanya ME, Macha IJ, Mlalila N. 2021. Aflatoxin contamination and recommendations to improve its control: a review. *World Mycotoxin Journal* 14:27–40
19. Udomkun P, Wiredu AN, Nagle M, Müller J, Vanlauwe B, et al. 2017. Innovative technologies to manage aflatoxins in foods and feeds and the profitability of application – A review. *Food Control* 76:127–38
20. Bandyopadhyay R, Ortega-Beltran A, Akande A, Mutegi C, Atehnkeng J, et al. 2016. Biological control of aflatoxins in Africa: current status and potential challenges in the face of climate change. *World Mycotoxin Journal* 9:771–90
21. Xu F, Baker RC, Whitaker TB, Luo H, Zhao Y, et al. 2022. Review of good agricultural practices for smallholder maize farmers to minimise aflatoxin contamination. *World Mycotoxin Journal* 15:171–86
22. World Health Organization. 2010. *FAO/WHO expert meeting on the application of nanotechnologies in the food and agriculture sectors: potential food safety implications*. Meeting report. www.fao.org/docrep/012/i1434e/i1434e00.pdf
23. Awuchi CG, Amagwula IO, Priya P, Kumar R, Yezdani U, et al. 2020. Aflatoxins in foods and feeds: A review on health implications, detection, and control . *Bulletin of Environment, Pharmacology and Life Sciences* 9:149–55
24. Ortega-Beltran A, Bandyopadhyay R. 2021. Contributions of integrated aflatoxin management strategies to achieve the sustainable development goals in various African countries. *Global Food Security* 30:100559
25. Muhie OA, Bayisa AB. 2020. Is aflatoxin a threat to human-health in Ethiopia? A systematic review. *International Journal of Collaborative Research on Internal Medicine & Public Health* 12:1007–15

26. Boni SB, Beed F, Kimanya ME, Koyano E, Mponda O, et al. 2021. Aflatoxin contamination in Tanzania: quantifying the problem in maize and groundnuts from rural households. *World Mycotoxin Journal* 14:553–64
27. Atanda SA, Pessu P, Agoda S, Isong I, Adekalu O, et al. 2011. Fungi and mycotoxins in stored foods. *African Journal of Microbiology Research* 5:4373–82
28. Lavkor I, Var I. 2017. The control of aflatoxin contamination at harvest, drying, pre-storage and storage periods in peanut: the new approach. In *Aflatoxin-Control, Analysis, Detection and Health Risks*, ed. Abdulra'uf LB. InTech Open. pp. 45–64. doi: 10.5772/intechopen.68675
29. Mshanga JP, Makule EE, Ngure FM. 2023. Physical methods for reduction of aflatoxins exposure in groundnuts in some low-income countries: a review. *Current Research in Nutrition and Food Science Journal* 11:504–18
30. Gnonlonfin GJB, Hell K, Adjovi Y, Fandohan P, Koudande DO, et al. 2013. A review on aflatoxin contamination and its implications in the developing world: a sub-saharan African perspective. *Critical Reviews in Food Science and Nutrition* 53:349–65
31. Lizárraga-Paulín EG, Moreno-Martínez E, Miranda-Castro SP. 2011. Aflatoxins and their impact on human and animal health: an emerging problem. In *Aflatoxins - Biochemistry and Molecular Biology*, ed. Guevara-González RG. vol. 13. InTech Open. pp. 255–62. doi: 10.5772/26196
32. Payne GA, Widstrom NW. 1992. Aflatoxin in maize. *Critical Reviews in Plant Sciences* 10:423–40
33. Demet Ö, Oğuz H, Çelik İ, Adıgüzel H. 1995. Production of aflatoxin on wheat, corn, rice and peanut. *Eurasian Journal of Veterinary Sciences* 11(2):135–40
34. Gupta SK, Venkitasubramanian TA. 1975. Production of aflatoxin on soybeans. *Applied Microbiology* 29:834–36
35. Molyneux RJ, Mahoney N, Kim JH, Campbell BC. 2007. Mycotoxins in edible tree nuts. *International Journal of Food Microbiology* 119:72–78
36. Samarajeewa U. 1972. Aflatoxins in coconut products. https://dl.nsf.gov.lk/bitstream/handle/1/19885/COCOQ-23(3-4)-108.pdf?sequence=2
37. Cary JW, Rajasekaran K, Brown RL, Luo M, Chen ZY, et al. 2011. Developing resistance to aflatoxin in maize and cottonseed. *Toxins* 3:678–96
38. Hammami W, Fiori S, Al Thani R, Ali Kali N, Balmas V, et al. 2014. Fungal and aflatoxin contamination of marketed spices. *Food Control* 37:177–81
39. Arroyo-Manzanares N, Huertas-Pérez JF, García-Campaña AM, Gámiz-Gracia L. 2015. Aflatoxins in animal feeds: a straightforward and cost-effective analytical method. *Food Control* 54:74–78
40. Atherstone C, Grace D, Lindahl JF, Kang'ethe EK, Nelson F. 2016. Assessing the impact of aflatoxin consumption on animal health and productivity. *African Journal of Food, Agriculture, Nutrition and Development* 16:10949–66
41. Salifu AB. 2009. The role of biotechnology in meeting the biodiversity conservation challenge of Africa. In *Aspects of African Biodiversity: Proceedings of the Pan Africa Chemistry Network Biodiversity Conference, Nairobi, 10–12 September 2008*. Cambridge: RSC Publishing. pp. 58–64. doi: 10.1039/9781847559647-00058
42. Weledesemayat GT, Ahmed Assaye M, Gemeda N. 2016. *Aspergillus* species and aflatoxin contamination of pre and post- harvest maize grain in west Gojam, Ethiopia. *Journal of Food Science & Nutrition* 2:013
43. Guchi E. 2015. Implication of aflatoxin contamination in agricultural products. *American Journal of Food and Nutrition* 3:12–20
44. Marchese S, Polo A, Ariano A, Velotto S, Costantini S, et al. 2018. Aflatoxin B1 and M1: biological properties and their involvement in cancer development. *Toxins* 10:214
45. Kew MC. 2013. Aflatoxins as a cause of hepatocellular carcinoma. *Journal of Gastrointestinal & Liver Diseases* 22:1–2
46. Bbosa GS, Kitya D, Lubega A, Ogwal-Okeng J, Anokbonggo WW, et al. 2013. Review of the biological and health effects of aflatoxins on body organs and body systems. In *Aflatoxins - Recent Advances and Future Prospects*, ed. Razzaghi-Abyaneh M. vol. 12. InTech Open. pp. 239–65. doi: 10.5772/51201
47. Benkerroum N. 2020. Chronic and acute toxicities of aflatoxins: mechanisms of action. *International Journal of Environmental Research and Public Health* 17:423
48. Okoth S. 2016. *Improving the evidence base on aflatoxin contamination and exposure in Africa*. Health & Fitness. 116 pp.
49. Kebede A, Balina A, Tamiru Y. 2018. Review on aflatoxin and its impacts on livestock. *Journal of Dairy & Veterinary Sciences* 6:e555685
50. Richardson RC. 2018. *Chile peppers and mycotoxin contamination: Problems and solutions*. Final Report for the Agribusiness Project. United States Agency for International Development (USAID). https://agribusiness.org.pk/wp-content/uploads/2015/04/7.-Chili-Peppers-and-Mycotoxin-Report.pdf
51. Jiang Y, Ogunade IM, Vyas D, Adesogan AT. 2021. Aflatoxin in dairy cows: toxicity, occurrence in feedstuffs and milk and dietary mitigation strategies. *Toxins* 13:283
52. Visser ME, Schoonees A, Ezekiel CN, Randall NP, Naude CE. 2020. Agricultural and nutritional education interventions for reducing aflatoxin exposure to improve infant and child growth in low- and middle-income countries. *Cochrane Database of Systematic Reviews* 2020(4):CD013376
53. Pandey MK, Kumar R, Pandey AK, Soni P, Gangurde SS, et al. 2019. Mitigating aflatoxin contamination in groundnut through A combination of genetic resistance and post-harvest management practices. *Toxins* 11:315
54. Wu F, Khlangwiset P. 2010. Evaluating the technical feasibility of aflatoxin risk reduction strategies in Africa. *Food Additives & Contaminants: Part A* 27:658–76
55. James B, Adda C, Cardwell K, Annang D, Hell K, et al. 2007. Public information campaign on aflatoxin contamination of maize grains in market stores in Benin, Ghana and *Togo*. *Food Additives & Contaminants* 24:1283–91
56. Falade T. 2019. Aflatoxin management strategies in sub-saharan Africa. In *Mycotoxins - Impact and Management Strategies*, eds. Njobeh PB, Stepman F. Intech Open. pp. 109–22. doi: 10.5772/intechopen.78784