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Mini Review

Mycotoxins: A Threat to Food Security and Health

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Abstract

Multicellular filamentous fungi grown on the surface and inside of moist food secretes toxins in the form of their secondary metabolites which are commonly called mycotoxins. The presence of mycotoxins in food has been a burning issue and a threat to food security and safety. The global population has skyrocketed and continues to be, which has created a challenge of providing quality food to the consumers. Aflatoxins, prevalent in most of the food crops in Nepal as well have posed a risk to national food security. Moreover, the consumption of food products containing mycotoxins is a cause of several health hazards like cancer, gastrointestinal problems, and neuropsychiatric effects. Mycotoxins not only has affected humans but also animals. Prevention, decontamination, and inhibition of absorption of toxins have been done to manage and mitigate the effects of mycotoxins. Recent research on mycotoxins is focused on the development of new methods to detect and analyse masked mycotoxins obtained from various sources. This review shows the contribution of mycotoxin in the global food security issue as well as its deleterious effects on human and animal health.

Keywords: Aflatoxins; Decontamination; Food Security; Mycotoxins; Neuropsychiatric effects

Introduction

Mold is a type of multicellular filamentous fungus grown on the surface and inside of moist food. All grain product and food products which have a water activity less than 0.8 are susceptible to the fungal infection when a specific weather pattern occurs during the growing season. The specified group of fungi is capable of producing toxic substances known as mycotoxins. Mycotoxins are secondary metabolites produced by microfungi (molds) that are capable of causing disease and death in humans and other animals. (Ismaiel and Papenbrock, 2015). The term mycotoxin was first used in 1960 to describe the toxin associated with contaminated peanut in animal feed and loss of turkey in England (Turnkey-X-disease). The functions of mycotoxins are still not fully understood, perhaps they function as an insecticide, they might play a role in fighting against the plant defence to the fungus in some way to complete their ecological niche in nature (Richard, 2007). Unlike the bacterial toxins, the mycotoxins are non-pretentious and hence are not detectable by the immune systems of humans and animals. The mycotoxins are

usually heat-stable and are not destroyed by canning and similar processes.

The contamination of food with mycotoxins are unavoidable and unpredictable, which makes it a unique challenge for food safety (Lopez-Garcia *et al.* 1999). Food safety refers to limiting the presence of those hazards, whether chronic or acute, that may make food detrimental to the health of the consumer. As per the United Nations committee on world food security, food security means that all people, at all-time, have physical, social and economic access to sufficient, safe and nutritious food that meets food preferences and dietary needs for an active and healthy life. The presence of mycotoxins in food makes the food products unsafe for consumption, which eventually leads to the post-harvest loss and becomes a threat to food security. The growth of various fungi in agricultural products leads to yield reduction and quality deterioration with significant economic losses (Adeyeye, 2016).

Classification of Mycotoxins

The primary category of fungi which are responsible for the production of mycotoxins is *Aspergillus, Penicillium and Fusarium, Trichoderma, Trichothecium* (Richard, 2007). Many species of toxigenic molds have been known till date, but only a few of them, which affects the food crops like cereals and groundnuts are considered to be significant for humans (Adeyeye, 2016). The toxigenic fungi are broadly categorised into two categories, i.e. field fungi (e.g., *Clostridium, Fusarium, Alternaria* species) which gets access into seed during the development of plant and storage fungi (*Aspergillus, Penicillium* etc.). Which grows during storage. Mycotoxins are not only hard to define, but they are also challenging to classify (Hendrich, 2017). Some major types of mycotoxins are:

Aflatoxins (produced by *Aspergillus spp)* - Aflatoxin B1, B2, G1, G2, M1 and M2

Ochratoxin - Ochratoxin A, B, and C

Trichothecene (produced by *Stachybotrys*) - Satratoxin-H, Vomitoxin, and T-2 mycotoxins

Fumonisins - Fumonisin B1 and B2

(https://moldpedia.com/mycotoxins)

Global Food Security and Mycotoxins

The current challenge to feed 7.6 billion people globally with limited and gradually decreasing cultivable land and food produce has ultimately pose a risk to food security. The global population is to be expected to rise to 9 billion by 2040, and with this growth rate, it will hit 11 billion by 2100 (World Population Clock, 2015). Most of this global population feeds on three major crops and their products, i.e. Rice, Wheat and Maize. 60% of global energy intake is contributed by these three crops, which are acknowledged as the staple food. Unfortunately, Maize and Wheat are vulnerable to the risk of mycotoxins. Fungi being cosmopolitan and flourish under the same environmental conditions where maize and wheat can grow effectively has affected the quality of products and causing massive production loss. Annual food loss of 16% is attributed to microbial diseases out of which fungi alone has contributed about 80% (David *et al.* 2013). *Aspergillus, Penicillium and Fusarium, Trichoderma, Trichothecium* are some of the significant fungi groups producing mycotoxins like Aflatoxins, Fumonisins, Ochratoxins, etc. (Richard, 2007). FAO estimates that mycotoxins, produced by different groups of fungi, has affected one-third of global food crops (Krska *et al.*, 2012). The United States, the largest producer of corn, reported that 98% of samples were affected by at least one mycotoxin and 74% of corn contained more than two mycotoxins (Mycotoxin Survey in US corn, 2019). These alarming figures imply the amount of food lost due to contamination by mycotoxins, ultimately leading to a threat to global food security.

Table 1: Various fungi, their substrate and mycotoxins.

Fungi	Substrate	Mycotoxins
Aspergillus flavus	Maize,groundnut,oilseed,cottonseed	Aflatoxin (carcinogenic to humans)
Aspergillus parasiticus	Maize,groundnut,oilseed,cottonseed	
Aspergillus nomius	Maize,groundnut,oilseed,cottonseed	
Aspergillus ochraceus	Bakey Wheat	Ochratoxin (Potentially carcinogenic)
Aspergillus carbonerius	Grapes, Wine, Coffee	
Fusarium oxysporum	Wheat, Barley, Maize	Fumonisins (Hepatotoxic and Nephrotoxic)
Fusarium sp.	Wheat, Barley, Maize	T-2 Toxin
Penicillium verrucosum	Wheat, Barley, Maize	Ochratoxin (Potentially carcinogenic)
Claviceps purpurea	Rye	Ergot Alkaloid
Stachybotrys	Hay	Satratoxin

Source: (Bennett and Klich, 2003)

Nepalese Prospect

Mycotoxin monitoring in Nepal was first started in 1978 when FAO/ UNEP Regional Monitoring of Food Contaminants Project involved Nepal in which 150/850 food samples collected comprising of mainly Cereals, Pulses, Oilseeds, and Spices. were found contaminated with aflatoxin. Among them, Maize and Peanuts were most susceptible to aflatoxin contamination, during the period from 1980-1987 (Karki and Sinha, 1992). Maize production in Nepal is mostly in the hilly region, i.e. 72.85%. (Timsina *et al.* 2016)**.** Most of the population of hilly region and Himalayan region have maize as their staple food; also researches show that aflatoxin contamination in Maize and Peanuts, as well as their products, are higher in Nepalese context. Aflatoxins, produced by *Aspergillus flabus*, was found to me major mycotoxin contributor in Nepalese maize and maize products. More than 19% of maize and 28% of maize products were contaminated with aflatoxin; most of them belonged to the regions having high temperature and humidity (Holcomb and Thompson, 1991). Whereas, in the hills and mountains, the dominance of *Fusarium spp*. (*Fusarium oxysporum and F. gibbosum)* that produces toxins like Fumonisins, was found (Karki and Sinha, 1992). Hence, major maize producing areas of Nepal are at higher risk of mycotoxin contamination.

To sum up, the higher risk of mycotoxin contamination in staple food of most population in Nepal would eventually lead to the food security issue by making the produce unconsumable, considering its toxic effects on human as well as animal health.

Recent Studies On Mycotoxins

Mycotoxins have been the centre of interest for many researchers and scientists since 1961. Since mycotoxins are one of the major hazards for food security and health, several studies have been carried out to overcome the effects of mycotoxins. Many structurally related compounds that are either generated by plant metabolism or food processing can coexist together with the native toxins in the mycotoxin contaminated commodities (Galaverna *et al.* 2009). The mycotoxins either extractable conjugated or non-extractable bound mycotoxins remain present in the plant tissues and can easily escape the routine analysis and hence called as the "Masked mycotoxins" (Berthiller *et al.* 2013). These masked mycotoxins have the potential to transform from harmless when outside the body to harmful when inside. The most commonly occurring masked mycotoxins in food commodities are deoxynivalenol-3-glucoside (D3G), zearalenone-14-glucoside (Z14G), and zearalenone-14-sulfate (Z14S). These compounds are either totally or partially hydrolysed to release the parent aglycone after ingestion (Dall' Erta *et al.* 2013).

The extraction of mycotoxins from marine fungus also has one of the recent issues in the study of mycotoxins. Nine mycotoxins have been isolated from the fermentation broth of marine gorgonian-derived fungus *Aspergillus* sp. SCSGAF0093. Out of these nine mycotoxins (1-9), six of them were from aspergillic acid group toxin and the remaining three were from ochratoxins (Xu *et al.*, 2013).

Conventionally the mycotoxins were detected by the expensive high-performance liquid chromatography (HPLC), gas chromatography (GC), Flame ionisation (FID) or MS detectors and enzyme-linked immune sorbent assay (ELISA) techniques. The present day's interest is in the development of the user-friendly biosensors for the mycotoxin's detection. The biosensors used for the screening are the biomolecules (antibiotics, DNA and enzymes) and synthetic chemicals (aptamers, MIP, mimotopes, etc.). The biosensors are divided into two categories, i.e. labelled and label-free sensors, which are further categorised into competitive and non-competitive based on the detection strategy (Chauhan *et al.* 2016).

Mycotoxins and Health

Mycotoxins can cause several serious health issues. The effect can range from acute poisoning to long-lasting and uncurable problems like cancer, in humans (WHO, 2018), and in animals (Surai *et al.* 2008). Some of the serious health hazards caused by mycotoxins are discussed below:

Mycotoxins and Animal Health

Mycotoxins successfully reach into animal's body through ingestion, skin contact or inhalation of fungal metabolites. These metabolites come from different sources like contaminated feeds, fodders, forages, and silages (Gallo *et al.* 2015). Ochratoxin, produced by various species of *Aspergillus* and *Penicillium,* are nephrogenic and nephrocarcinogenic compounds and found to be occurring in kidney, liver, and blood of animals and transfer from animal feeds. Zearalenone (ZEA), produced by *Fusarium sp.,* is found to be affecting the reproductive health of animals. (Zain, 2011). Aflatoxin B1 produced by various strains of *Aspergillus flabus*, *A. parasiticus*, etc. are the most potent carcinogenic aflatoxin for animals (Peterson *et al.* 2007). Fumonisins (B_1 and B_2) are cancer-promoting metabolites produced by *Fusarium proliferatum* and *Fusarium verticillioides.* Trichothecene, produced by *Fusarium sp., Myrothecium sp., Phomopsis sp., Trichoderma sp.* etc. inhibit eukaryotic protein synthesis, interfering in the initiation, the elongation and termination steps of protein synthesis in the animal body. Deoxynivalenol (DON), one of the essential trichothecenes and most commonly found in grains, if ingested by animals in higher doses cause nausea, vomiting, and diarrhoea (Edite *et al.*, 2014). Above shown are just some of the detrimental effects of mycotoxin in animals. Many other toxins are present in feedstuffs, which has contributed to ruining animal health. In the nation like Nepal, where

mycotoxin monitoring in feed is rarely adopted, along with the degrading health of animals, human health is also posed at risks due to the consumption of contaminated animal products. Meat and milk products produced by the animals who are affected by mycotoxin, transfer these toxins to human beings through their products.

Mycotoxins and Human Health

Mycotoxins pose a severe risk to human health. From acute symptoms and illness right after the consumption of contaminated food, to the initiation of long-lasting and sometimes non-curable diseases like cancer and immune deficiency have been reported till date. Also, mycotoxins are globally distributed and have contaminated a substantial share of the world's staple food and food products. Among hundreds of mycotoxins discovered till date, only a few of them caught the concern of scientists as they were found to be more harmful to humans. Aflatoxin, one of them, is considered to be the most poisonous toxin produced by molds *Aspergillus flavus* and *Aspergillus parasiticus.* Having a wide variety of host range, i.e. maize, wheat, rice- the three leading staple food of globe, pulses, spices, milk and milk products, etc., aflatoxin has affected a considerable sum of population all-round the globe. Ingestion of aflatoxin in large amount would result in liver damage and also genotoxicity, i.e. damaging of DNA following cancer. Ochratoxin A, produced by various species of *Aspergillus* and *Penicillium*, are identified to have a considerable effect in kidney damage. Patulin, also produced by some of the spices of *Aspergillus*, *Penicillium* and *Byssochlamys*, often detected in apple-related products, have been reported for nausea, gastrointestinal disturbances and vomiting in human beings. Fusarium species that are responsible for the production of different mycotoxins like deoxynivalenol (DON), nivalenol (NIV), T-2 and HT-2 toxins, zearalenone (ZEN), fumonisins, etc. has led to severe health issues: rapid irritation of skin and irritation, intestinal mucosa and lead to diarrhoea. Fumonisins have been associated with oesophagal cancer in humans (WHO, 2018). Moreover, long-term exposure to mycotoxins found to be related to Neuropsychiatric symptoms like including an inability to stand on one's toes, inability to walk in a straight line with eyes closed, short-term memory loss, altered blink-reflex latency, verbal recall impairments, etc. (Ratnaseelan *et al.* 2018).

To minimise the risk of mycotoxin in the foods we consume, it is necessary to inspect what we eat. Grains (corn wheat, sorghum, rice), nuts (peanuts, almonds, hazelnuts, walnuts) etc. should be appropriately inspected before consuming and sorting out the infected ones. Any mouldy grains and foodstuffs must be avoided to prevent the contamination from the toxins. As prevention is always better than cure, proper post-harvest handling of food grains: drying of grains before to maintain the optimum moisture level, avoiding any damage and injuries during processing, storage, as injured ones are susceptible to mold attack. Storage units must be maintained properly according to the requirement of the grains to be stored. Too dry or too humid units are prone to mold contamination. Above all, we should include a diverse range of foodstuffs in our diet, which not only helps to reduce mycotoxin exposure but also improve our nutrition intake, enabling us to build immunity.

Management of Mycotoxins in Food

Mycotoxins in agricultural products are the primary cause of health hazard to people, food security hazard and economic problems. The consumption of food commodities which are contaminated with mycotoxins can cause chronic mycotoxicosis and may lead to death (Adegoke. and Letum, 2013). So, the prevention of fungal growth on agricultural commodities to prevent mycotoxin contamination is of utmost importance (Leibetseder, 2006). Several approaches have been considered for the management and decontamination of mycotoxins in food and agricultural commodities. For avoiding the harmful effects of mycotoxins in food three possibilities can be regarded as i.e.

- Prevention of contamination
- Decontamination of mycotoxin- containing food and feed
- Inhibition or absorption of mycotoxin content of absorbed food into the digestive tract (Juodeikiene *et al.* 2012). By using the techniques such as field management, harvest management, using resistant varieties, use of biological and chemical agents (preharvest methods), improved drying methods, good storage condition, and irradiation (post-harvest methods) the contamination of mycotoxins in food can be prevented Adegoke and Letum, 2013). The mycotoxin contamination in food products can also be prevented by using some selected microorganisms or enzymes which are capable of detoxifying mycotoxins (Jard *et al.* 2011).

The decontamination of mycotoxins can be achieved either by physical, chemical or biological methods. The dry cleaning of the grains and milling operation can result in a reduced level of mycotoxins in the flour (Juodeikiene *et al.* 2012). Since the mycotoxins are heat stable, the heat applied during the processing of the food does not significantly affect the mycotoxin level. The physical absorbents of selective binding nature are also used commercially for the mycotoxin decontamination. The use of chemical agents such as alkali and oxidising agents have also been seen in some countries for this purpose, but this process has got a demerit of reducing the nutritional value of the food products. The biological method, i.e. the use of microorganisms such as yeast (*S. cerevisiae and Candida krusei*) and Lactic acid bacteria (LAB) has been best suited for the mycotoxin decontamination as this process tends to improve the palatability and there is no significant loss in the nutritive values of food (ibid). The management of

mycotoxins in food can also be done by using the principles of Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practices (GMP) (Awad *et al.* 2010).

Conclusion

Mycotoxin exposure has been a significant problem among the global population in the context of health. About one-fourth of the food is contaminated with mycotoxins, and if this issue is not addressed on time, it could be a significant threat to global food security. Several types of researches and studies have shown that long term exposure to mycotoxins would result in serious health problems like liver damage, cancer, and even neuropsychiatric symptoms in humans. Not only in humans, but the animal population has also been affected by mycotoxins, which have resulted in degraded animal health and production of contaminated animal products. With proper handling of food products, i.e. pre-harvest and post-harvest handling, we can mitigate the occurrence of mycotoxins in food. Sushant Puri, Shuvam Shingh, Priya Tiwari1

Author's Contribution

All authors designed the research plan, performed experimental works & collected the required data. Sushant Puri and Shuvam Shingh prepared the manuscript & critical revised the manuscript. All authors finalized the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

References

Adegoke and Letum (2013) Strategies for the Prevention and Reduction of Mycotoxins in Developing Countries. In Mycotoxin and Food Safety in Developing Countries. DOI: 10.5772/52542

Adeyeye SAO (2016) Fungal mycotoxins in foods: A review. *Cogent Food and Agriculture* **2**(1) DOI: 10.1080/23311932.2016.1213127

Awad WA, Ghareeb K, Böhm J, and Zentek J (2010) Decontamination and detoxification strategies for the Fusarium mycotoxin deoxynivalenol in animal feed and the effectiveness of microbial biodegradation. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment* **27**(4): 510–520. DOI: 10.1080/19440040903571747

Bennett JW and Klich M (2003) Mycotoxins. *Clinical Microbiology Reviews* **16**(3): 497–516. DOI: 10.1128/cmr.16.3.497-516.2003

Berthiller F, Crews C, Dall'Asta C, Saeger SD, Haesaert G, Karlovsky P and Stroka J (2013) Masked mycotoxins: A review. *Molecular Nutrition and Food Research* **57**(1): 165–186. DOI: 10.1002/mnfr.201100764

Chauhan R, Singh J, Sachdev T, Basu T and Malhotra BD (2016) Recent advances in mycotoxins detection. *Biosensors and Bioelectronics* **81**: 532–545. DOI: 10.1016/j.bios.2016.03.004

Dall'Erta A, Cirlini M, Dall'Asta M, Del Rio D, Galaverna G, and Dall'Asta C (2013) Masked mycotoxins are efficiently hydrolysed by human colonic microbiota releasing their aglycones. *Chemical Research in Toxicology* **26**(3): 305–312. DOI: 10.1021/tx300438c

David Moore GDR and Anthony PJT (2013) 21St Century Guidebook To Fungi. Choice Reviews Online, 49(07), 49-3854-49–3854. DOI: 10.5860/choice.49-3854

Edite Bezerra da Rocha M, Freire F da CO, Erlan Feitosa Maia F, Izabel Florindo Guedes M, and Rondina D (2014) Mycotoxins and their effects on human and animal health. Food Control, 36(1), 159–165. DOI: 10.1016/j.foodcont.2013.08.021

Galaverna G, Dallsta C, Mangia MA, Dossena A, and Marchelli R (2009) Masked mycotoxins: An emerging issue for food safety. Czech Journal of Food Sciences, 27(SPEC. ISS.), S89–S92. DOI: 10.17221/1064-CJFS

Gallo A, Giuberti G, Frisvad JC, Bertuzzi T, and Nielsen KF (2015) Review on Mycotoxin Issues in Ruminants: Occurrence in Forages, Effects of Mycotoxin Ingestion on Health Status and Animal Performance and Practical Strategies to Counteract Their Negative Effects. Toxins, 7(8), 3057–3111. DOI: 10.3390/toxins7083057

Hendrich S (2017) MYcotoxins. Food Toxicology: Current Advances and Future Challenges, 16(3), 179–198. DOI: 10.1201/9781315161075

Holcomb M and Thompson HC (1991) Analysis of Aflatoxins (B1, B2, G1, and G2) in Rodent Feed by HPLC Using Postcolumn Derivatization and Fluorescence Detection. Journal of Agricultural and Food Chemistry, 39(1), 137–140. DOI: 10.1021/jf00001a026

Ismaiel A and Papenbrock J (2015) Mycotoxins: Producing Fungi and Mechanisms of Phytotoxicity. Agriculture, 5(3), 492–537. DOI: 10.3390/agriculture5030492

Jard G, Liboz T, Mathieu F, Guyonvarch A and Lebrihi A (2011) Review of mycotoxin reduction in food and feed: from prevention in the field to detoxification by adsorption or transformation. Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment, 28(11), 1590–1609. DOI: 10.1080/19440049.2011.595377

Juodeikiene G, Basinskiene L, Bartkiene E and Matusevicius P (2012) Mycotoxin Decontamination Aspects in Food, Feed and Renewables Using Fermentation Processes. In Structure and Function of Food Engineering. DOI: 10.5772/46184

Karki TB and Sinha BP (1992) Mycotoxin contamination of foods and feeds in Nepal. Mycotoxin Prevention and Control in Food grains.

Krska R, Richard JL, Schuhmacher R, Slate AB and Whitaker TB (2012) Guide to Mycotoxins.

Leibetseder J (2006) Chapter 15 Decontamination and detoxification of mycotoxins. In Biology of Growing

Animals DOI: 10.1016/S1877-1823(09)70102-X (Vol. 4, pp. 439–465).

Mycotoxin Survey in US corn: March 2019 update: Biomin.net (2019) https://www.biomin.net/en/mycotoxinsurvey/?tx_news_pi1%5Bnews%5D=2333andcHash=7879aa68fd41915fb9ae5f59ff62911

Peterson SW, Ito Y, Horn BW and Goto T (2007) Aspergillus bombycis, a New Aflatoxigenic Species and Genetic Variation in Its Sibling Species, A. nomius. Mycologia, 93(4), 689. DOI: 10.2307/3761823

Lopez-Garcia R., Park DL and Phillips TD (1999) Integrated mycotoxin management systems. Food, Nutrition and Agriculture, http://www.fao.org/docrep/X2100T/x2100t07.htm

Ratnaseelan AM, Tsilioni I and Theoharides TC (2018) Effects of Mycotoxins on Neuropsychiatric Symptoms and Immune Processes. Clinical Therapeutics, 40(6), 903–917. DOI: 10.1016/j.clinthera.2018.05.004

Richard JL (2007) Some major mycotoxins and their mycotoxicoses-An overview. *International Journal of Food Microbiology* **119**(1–2): 3–10. DOI: 10.1016/j.ijfoodmicro.2007.07.019

Surai PF, Mezes M, Melnichuk SD and Fotina TI (2008) Mycotoxins and animal health: from oxidative stress to gene expression mikotoksini i zdravlje životinja: od okcidacijskog stresa do ispoljavanja gena. 50(June 2015).

Timsina KP, Ghimire YN and Lamichane J (2016) Maize production in mid-hills of Nepal: from food to feed security. *Journal of Maize Research and Development* **2**(1): 2467–9305 DOI: 10.3126/jmrd.v2i1.16212

WHO (2018) Mycotoxins, https://www.who.int/news-room/fact-sheets/detail/mycotoxins.

World Population Clock – Worldometers (2015) Retrieved June 25, 2019, from Worldometers.info. website: https://www.worldometers.info/world-population/

Xu X, He F, Zhang X, Bao J and Qi S (2013) New mycotoxins from marine-derived fungus Aspergillus sp. SCSGAF0093. *Food and Chemical Toxicology* **53**: 46–51. DOI: 10.1016/j.fct.2012.11.037

Zain ME (2011). Impact of mycotoxins on humans and animals. *Journal of Saudi Chemical Society* **15**(2): 129–144. DOI: 10.1016/j.jscs.2010.06.006