A Mini Review on Mycotoxins in Food and Feed: A Global Threat

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Abstract

There are many toxic compounds produced by fungi and one of them is mycotoxin. Mycotoxins have scourged mankind for thousands of years causing death, hallucination and misery. Natural outbreaks of mycotoxicosis occur world-wide, from the humid tropics to Siberia. Approximately 25% of the worldwide crop production is Contaminated with mycotoxins. Mycotoxin ingestion is considered a severe health problem for both humans and animals. Regulations that limit the levels of mycotoxins in foods and feed because of their public health significance also can affect food security/food availability, especially in developing countries. It is concluded that mycotoxins are a global problem that requires a global solution to prevent or reduce the development of mycotoxigenic fungi, their insect vectors and the resulting mycotoxin contamination of agricultural crops in the field and in storage.

Keywords: Mycotoxins; Toxic; Food and Feed; Risk

Introduction

Mycotoxins are secondary metabolites produced by filamentous fungi that have deleterious effects on human and animal consumers (Nicholson 2004), acutely as well as chronically [1]. Mycotoxins are structurally diverse, deriving from a number of biosynthetic pathways and their effect upon consumers is equally diverse ranging from acutely toxic to immunosuppressive or carcinogenic [2]. Poor harvesting practices, improper drying, handling, packaging, storage and transport conditions contribute to fungal growth and increase the risk of mycotoxin production [3]. Although the climate in a particular country may not favor the elaboration of a specific mycotoxin, such as aflatoxin, the problem may be imported from another country in the form of agricultural products, such as peanuts or maize. Regardless of decades of extensive research, mold infection still remains a challenging problem [4]. The occurrence of mycotoxin in the food commodities can be dated as early as in the tenth century (Sabran., et al. 2013). Fusarium mycotoxins produced by different fungal species are common contaminants of food and feed ingredients [5]. It has been estimated that about 25% of the world crops are contaminated with known mycotoxins produced by a variety of toxigenic fungi [6,7] and are affected by mycotoxins [6,7]. The five most important naturally occurring mycotoxins in human foods and animal feeds are aflatoxin, ochratoxin, deoxynivalenol, zearalenone and fumonisin. Risk assessment is used to manage the risk from mycotoxins to protect human and animal health. Conventional risk assessment has two major components, i.e., exposure assessment and hazard assessment, which data are used to establish Maximum Tolerated Levels (MTLs). The MTLs proposed by developed countries apply to commodities that they import and to foodstuffs consumed within their borders, but not to agricultural products that they export. Thus, conventional risk assessment has helped manage the risk from mycotoxins in developed countries but has not helped in developing countries that import foodstuffs or receive food aid. The objective of this mini review article was to remind the long-standing deleterious effects of mycotoxins on humans and livestock health.

Mycotoxigenic fungi

Globally, the five most important mycotoxin-producing fungi are [8]. That Aspergillus flavus, Aspergillus ochraceus, Penicillium verrucosum, Fusarium graminearum and Fusarium verticillioides. The five most important mycotoxins [9]. Occur naturally in agricultural products are: aflatoxin produced by Aspergillus flavus; ochratoxin produced by Aspergillus ochraceus and Penicillium verrucosum; deoxynivalenol and zearalenone produced by Fusarium graminearum; and fumonisin produced by Fusarium verticillioides. Human diseases that have been associated with two of these mycotoxins in foods are: acute toxic hepatitis and liver cancer with aflatoxin; and esophageal cancer and neural tube defects with fumonisin. Aflatoxins are chemically and biologically active secondary metabolites with an unexplored role in fungal development that produced by certain molds, which grow in soil, cereals, nuts, fruits, decaying vegetation, hay and grains [10]. Aflatoxins are real public health hazards cause acute and chronic disorders. Aflatoxins can be found in animal tissues and milk after ingestion of contaminated feed. Deoxynivalenol and zearalenone are the most common Fusarium mycotoxins, which are commonly spreading contaminants in animal feed, mostly cereals and forages. These two mycotoxins are characteristically constant under varying environmental conditions and have been identified to cause a diversity of toxic effects in humans, farm animals and experimental animals. Mycotoxins have undoubtedly presented a global problem to human and animal health since the earliest times [11] and this threat will only increase as the demand on the available food supply increases in response to the growth of the world population.

Economic losses

Mycotoxins are secondary fungal metabolites associated with adverse human health and animal productivity consequences. Severe health problems, including severe gastrointestinal tract diseases and malignant tumors, have been reported in both animals and humans, due to long-term exposure to mycotoxins in the diet [12]. High concentrations of mycotoxins in feed cause major adverse effects; although in a number of cases, mycotoxin levels are too low to produce immediate clinical symptoms. Chronic-level exposure of farm animals to mycotoxins generally results in reduced growth rate, reproductive problems and increased incidences of different non-infectious and infectious diseases, the latter mostly due to repression of the immune function [13]. Fusarium mycotoxins are the root cause of substantial economic losses in animal husbandry. Losses due to mycotoxins in developing countries extend beyond the losses in grain and animal production, as export markets may be lost to the stricter limits and possible non-tariff barriers that result from mycotoxin regulations. Food and Agriculture Organization of the United Nations (FAO) estimates of world losses of foodstuffs due to mycotoxins are around 1,000,000,000 t per year [14]. Annual costs connected with mycotoxin occurrences in food/feed are continuing to rise [15]. The economic models used to make this estimate included the evaluation of product spoilage effects, human health effects with respect to disability and premature death due to aflatoxin-related primary liver cancer and livestock health effects due to reduced feed efficiency and increased mortality.

Risk assessment and regulation

A problem cannot be controlled before it is recognized and acceptance by governments of developed and developing countries that mycotoxins represent a serious health hazard in addition to serving as a trade barrier with significant economic impacts, is a matter of urgency. The most important challenge faced in mycotoxin research and management in developing countries is the development of sustainable prevention and control strategies based on appropriate and feasible methods within the context of making available food for one of the fastest growing populations in the globe. The risks posed by mycotoxins in food present enormous difficulties to these countries and the international organizations responsible for controlling mycotoxin levels. Conventional risk assessment of mycotoxins has two major components, i.e., exposure assessment and hazard assessment [16,17]. Exposure is calculated from food intake and naturally occurring levels of a mycotoxin and expressed as the Probable Daily Intake (PDI). Hazard is calculated from toxicological studies in experimental animals and is expressed as the Tolerable Daily Intake (TDI). The PDI and TDI data are used to assess the risk of a mycotoxin and establish MTLs [3]. People in rural areas of developing countries, who are at the highest risk from mycotoxins in staple foods, particularly subsistence farmers, are completely unprotected by mycotoxin regulations [1]. International consensus on tolerable levels for mycotoxins

is very difficult to reach due to deficiencies in the risk database and inconsistencies in risk management decisions in spite of concerted action by international organizations and institutions such as FAO with the Codex Alimentarius and Joint FAO/WHO Expert Committee on Food Additives (JECFA) to address all of the components of the mycotoxin issue, including new methods for risk evaluation and control strategies [14].

Possible solutions

Disease outbreaks due to the consumption of contaminated food and feedstuff are a recurring problem worldwide. The major factor contributing to contamination are microorganisms, especially fungi, which produce low-molecular-weight compounds as secondary metabolites, with confirmed toxic properties referred to as mycotoxins. Several mycotoxins reported to date are cosmopolitan in distribution and incur severe health-associated risks (including cancer and neurological disorders). Hence, creating awareness among consumers, as well as developing new methods for detection and inactivation is of great importance for food safety [3]. The ultimate solution to the global mycotoxin problem is not regulation, but reduction of fungal infection and mycotoxin levels in crop plants [11]. Attempts to achieve this goal by conventional plant breeding have not been very successful for various reasons including the lack of major single genes and difficulties in selecting appropriate germplasm due to time-consuming and expensive mycotoxin analyses [4,18]. Molecular markers are being used increasingly to facilitate selection and to combine resistance genes from different sources in order to develop varieties with high yields and low mycotoxin levels, but potentially commercial lines have yet to be identified. The most promising approach for innovative solutions is biotechnology. The potential of transgenic resistance to mycotoxigenic fungi and/or their mycotoxins as biotechnology solutions for the global mycotoxin problem is receiving intensive international attention. The European Union continues to make mycotoxin standards more stringent by lowering the MTL in imported agricultural products on the one hand, while prohibiting the importation of Genetically Modified crops on the other. This impasse is a serious obstacle to the implementation of biotechnology solutions to the mycotoxin problems of exporting countries [1]. Losses can be minimized by a multi-factorial food chain mycotoxin management approach. Four principles underlie this approach: (i) establishing science-dependent, realistic and risk-based regulatory levels that are proportionate to the risk incurred and not overtly protective, (ii) systematically managing mycotoxin risks through country-specific practical recommendations and national action plans, (iii) implementing adequate tools, e.g. good agricultural practices and a HACCP system, along the food chain that prevents, controls or reduces the damage resulting from fungal contamination and (iv) adopting early warning systems based on climatic models that predict when mycotoxin outbreaks are likely [14]. Development of new genetically modified plants by the application of genetic engineering that might be resistant to fungal invasion might also prove to be a good option. Developing new protocols and strategies to compare the costs and benefits of various controlling agents against fungal pathogens and mycotoxin production might be beneficial for economic stability of a commodity or an agricultural area [3]. Moreover, the use of innovative processing techniques such as infrared roasting, non-ionizing radiations, cold atmospheric pressure plasma and neutral electrolyzed water will greatly enhance the safety of numerous food or feed commodities with diverse physical attributes or chemical compositions [15]. Emphasis should be laid towards development of newer low-cost mycotoxin detection instruments, which are portable, reliable and easy to handle at field levels [19,20].

Conclusion

Mycotoxins are secondary fungal metabolites associated with adverse consequences on human health and animal productivity. Major loss of fresh harvest that renders it to be an impediment for safe consumption can be attributed mainly to 3 factors: biological (storage pests), microbial (bacteria, fungi) and chemical (insecticide, fungicide residues). These 3 factors, singly or in combination, can readily react with the substrate or the raw material leading to the production of off-flavors, discoloration of the product and reduction in nutritional value. It is generally claimed that natural products are safe worldwide, but fungal toxins have been detected in various food commodities from many parts of the world and have been recognized to be one of the most dangerous contaminants of food and feed. However, contamination of human food or animal or feed via natural biotoxins produced by microbes might result in outbreaks of several diseases. Among the microbes, fungal toxins assume more importance due to their worldwide distribution. The use of innovative processing tech-
niques such as infrared roasting, non-ionizing radiations, cold atmospheric pressure plasma and neutral electrolyzed water will greatly enhance the safety of numerous food or feed commodities with diverse physical attributes or chemical compositions. However, wide gaps still exist on the toxicological effects of feeding animal's mycotoxin-contaminated feeds. Research in this field is a necessity as there is every possibility that the toxins will enter the human food chain. Further research also needs to be focused on the generation of data dealing with epidemiological and toxicity effects, especially in humans. Contamination of food and agricultural commodities by various types of toxigenic molds (fungi) is a serious and a widely neglected problem. In conclusion, implementation of strict quarantine rules with regard to mycotoxin contamination has to be made mandatory worldwide.

Bibliography


