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Research Article

Mycotoxin Management in Agriculture

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ABSTRACT

This review was done to highlight the worldwide contamination of foods and feeds with mycotoxins as a significant problem. Mycotoxins are secondary metabolites of moulds that have adverse effects on humans, animals, and crops that result in illnesses and direct economic losses in crop yield and stored agricultural products. Aflatoxins, ochratoxins, trichothecenes, zearelenone, fumonisins, tremorgenic toxins, and ergot alkaloids are the mycotoxins of greatest agro-economic importance. Some moulds are capable of producing more than one mycotoxin and some mycotoxins are produced by more than one fungal species. Often more than one mycotoxin is found on a contaminated substrate. Factors influencing the presence of mycotoxins in foods or feeds include environmental conditions related to storage that can be controlled. Other extrinsic factors such as climate or intrinsic factors such as fungal strain specificity, strain variation, and instability of toxigenic properties are more difficult to control. The challenges in mycotoxin management are enormous due to the frequency, the complexity and variability in occurrence with several aspects make the management and control of mycotoxins difficult. Monitoring or surveillance of mycotoxin levels in crops and products is an important management tactic and it can be implemented at both pre-harvest and post-harvest stages.

INTRODUCTION

It is difficult to define mycotoxin in a few words. All mycotoxins are low-molecular-weight natural products (i.e., small molecules) produced as secondary metabolites by filamentous fungi. These metabolites constitute a toxigenically and chemically heterogeneous assemblage that is grouped together, only because the members can cause disease and death in human beings and other vertebrates. Not surprisingly, many mycotoxins display overlapping toxicities to invertebrates, plants, and microorganisms (Bennett, 1987). Depending on the definition used, and recognizing that most fungal toxins occur in families of chemically related metabolites, some 300 to 400 compounds are now recognized as mycotoxins, of which approximately a dozen groups regularly receive attention as threats to human and animal health (Cole and Cox, 1981). While all mycotoxins are of fungal origin, not all toxic compounds produced by fungi are called mycotoxins. Mycotoxins have received considerable attention especially over the last three decades. Mycotoxicology is currently a subject of international importance. The problem of mould damage and the hazard of consuming damaged grains have been recognized since historical times. In areas of the Indo-Gangetic plains, for instance, traditional farmers have practised appropriate post-harvest measures to preserve crops. Expressions like "dry the grains well and keep dry grains dry" have been passed from one generation to the next. The problem of ergotism resulting from the infestation of rye by *Claviceps* has been known since biblical times and is now recognized as having been an important cause of human mortality in medieval Europe. The use of wheat, which is highly susceptible to *Fusarium* species producing trichothecenes, increased during this period and has been linked to the plague epidemics of the time. During the first half of this century, the possibility of human diseases occurring as a result of the consumption of mould-damaged rice and wheat was raised in Japan and other Asian countries. In the USSR, there was also awareness of risks from eating overwintered millet. However, the serious worldwide concern about mycotoxins began in the early 1960s after it was discovered in the United Kingdom that Turkey "X" disease is caused by aflatoxins. (Bhat and Miller, 1998).

The Mycotoxins

- **Patulin.** Produced by *Penicillium*, *Aspergillus*, and other genera, patulin most commonly infects non-intact apricots, grapes, peaches, pears, apples,olives, cereals, and low-acid fruit juices (Sewram et al., 2000; Speijers, 2004). Apple juice has historically been a high concern for contamination.

- **Ochratoxin.** This mycotoxin occurs in a large variety of foods because it is produced by several strains of *Penicillium* and *Aspergillus* spp. that have varying physiologies and ecologies. Ochratoxin A, the main toxin in this group, is found in infected wheat, corn, and oats, and cheese and meat products of animals consuming ochratoxin contaminated grains (Aish et al., 2004). Although the toxin is reported to occur in foods around the world, the main regions of concern are Europe and, for some foods, Africa.

- **Zearalenone.** A mycoestrogen, zearalenone has attracted recent attention because of concerns that environmental estrogens have the potential to disrupt sex steroid hormone functions. Genotoxicity is a reported concern. Occasional outbreaks of zearalenone mycotoxicosis in livestock are known to cause infertility. This toxin is found almost entirely in grains, in highly variable amounts ranging from a few nanograms/gram to thousands of ng/g.

- **Aflatoxins.** These mycotoxins occur in several chemical forms, designated aflatoxin B1, B2, G1, G2, and M1. The “B” and “G” designations refer to the blue or green fluorescence observed upon exposure of the toxin to ultraviolet radiation. M1 is the predominant metabolite of aflatoxin B1 (AFB1) in milk from lactating humans and animals consuming AFB1- contaminated food or feed. Aflatoxins may contaminate many crops, including peanuts, corn, cottonseed, Brazil nuts, pistachios, spices, copra (dried coconut), and figs. Contamination may be widespread in hot and humid regions of the world, such as Africa and some parts of China. Human aflatoxicoses continue to be an occasional, serious problem. Some food processing methods can reduce or eliminate aflatoxins. There are reports of reformation or reactivation of aflatoxins post-process. Simultaneous hepatitis B and infections commonly occur in regions with high rates of hepatocellular carcinoma (HCC). Combination of hepatitis B and AFB1 exposure increased relative risk for HCC to 59 (Qian et al.,1994); thus, AFB1 is an independent and possibly strongly potentiating factor for human HCC.

- **Trichothecenes.** Approximately 180 trichothecenes are known to exist; only a few, of which deoxynivalenol (DON) is the most prevalent, are significant to human health. The related 3-acetyl DON, T-2 toxin, and nivalenol also occur with some regularity, however. Although human DON exposure may be within the range of doses shown to be immunotoxic in rodents, human exposures and responses to this toxin are ill defined and more work is needed to define the human risk associated with this contaminant.

- **Fumonisins.** These mycotoxins are produced by the maize pathogens *Fusarium verticillioides* and *Fusarium proliferatum*, and at a very low levels, by *Alternaria* in black end stem rot in tomatoes (Chen et al., 1992), asparagus, and garlic (Seefelder n et al., 2002). At least 15 related fumonisin compounds have been identified. Fumonisins are highly water-soluble and unlike other mycotoxins, because they do not have an aromatic structure or a unique chromophore for easy analytical detection. Fumonisins are associated with increased incidence of esophageal cancers in South Africa and China (IARC, 1993) and may be a risk factor in neural-tube and related birth defects (Marasas et al., 2004). Maize-containing foods are the major fumonisin concern for the food industry. Fumonisin levels in U.S. corn were relatively high between 1988 and 1991, but have been low (<0.5 ng/g) in recent years. There are a few reports of high fumonisin levels (up to 150 µg/g) in home-grown corn consumed in China and South Africa. Most commercial foods, however, contain 500 ng/g or less due to low fumonisin levels in corn and ingredient quality control (Shephard et al., 1996). Fumonisins are extremely stable to a variety of heat/chemical processing operations.

Mycotoxin Effects

Under some conditions, moulds may produce potent mycotoxins at levels that may adversely affect animal production and health. There is also a potential public health concern when milk or other human foods contain a level of aflatoxin that exceeds the maximums established by the Food and Drug Administration (FDA). While moderate effects may appear initially, more obvious reductions in performance often result within a few days to several weeks of ingestion of the contaminated feed or ration. Milk production may drop by more than 15%. Young animals nursing an infected dam may do poorly due to appreciable aflatoxin in her milk. Off-feed, ketosis or acetonemia, and displaced abomasum (DA) problems may rise sharply. Some animals may have diarrhoea or show signs of haemorrhaging. Marked estrogenic effects such as swollen vulvas and nipples or rectal and vaginal prolapse may occur when some mycotoxins are present. Abortion or a reduction in conception or litter size may even result. Some effects may occur at levels lower than those indicated, since lower concentrations may not have been researched or were not encountered in documented field cases. Higher intakes might be necessary in other cases, since the mycotoxin indicated may have been only one of several which were not identified through testing. Symptoms or clinical indications of appreciable liver or kidney damage may occur; increasing the likelihood that mycotoxicity is the causative factor. Such damage often occurs at high or prolonged intakes of mycotoxins. The effects of mycotoxins are accumulative over a period of time. The presence of more than one mycotoxin may increase these effects. Chronic effects are more often noted than acute, sudden ones. Often animals do not die or show acute signs early in a mycotoxicity. It may take several days to several weeks to cause marked changes in performance or acute symptoms. Aflatoxins are usually present at lower levels, and animals are not as sensitive to them. Fusarium toxins, especially trichothecenes, are more likely to affect livestock. Trichothecenes include T-2, HT-2, deoxynivalenol (DON or vomitoxin) and diacetoxyscipernol (DAS). Zearalenone, another Fusarium toxin, is prevalent and more often occurs during storage than in the field. Fumonisin affects horses drastically and quickly after ingestion. Mycotoxins may develop in almost any feedstuff during the growing season, at harvest, or during storage. Cool, wet weather favours Fusarium toxins, while hot, humid weather encourages aflatoxin formation. While grains receive the most attention, by-product feeds, protein concentrates, finished feeds, oilseeds, wet brewers' grains, food wastes, and forages may also contain mycotoxins. Whole-plant corn silage and haylage are more likely to be contaminated than hays. Heat-processing and ensiling do not destroy mycotoxins. It is important to note that signs of mycotoxicity mimic those of other metabolic and infectious diseases, including ketosis, Johnes, *Salmonell*a, clostridial infections, and some poisonous weeds such as pigweed.

Table 1: Some mycotoxins, their sources and potential toxicities

Toxins	*Producing fungi*	*Toxicities*
Aflatoxin	*/Aspergillus flavus/*	Hepatocarcinogen
	/Aspergillus parasiticus/	and fatty liver
Citreoviridin	*/Penicillium viridicatum/*	Cardiac beri-beri
Citrinin	*/Penicillium vindicatum/*	Nephrotoxin
	/Penicillium citrinum/	
Cyclochlorotine	*/Penicillium islandicum/*	Hepatotoxin
Cytochalasin E	*/Aspergillus clavatus/*	Cytotoxicity
Maltoryzine	*/Aspergillus oryzae/*	
Ochratoxins	*/Aspergillus ochraceus/*	Hepatotoxin
Patulin	*/Penicilliumc-expansum/*	Brain & lung hemmorrhage
	/Penicillium patulum/	and carcinogenicity
PR Toxin	*/Penicillium requeforti/*	
Rubratoxin	*/Penicillium rubrum/*	Liver hemmorrhage and fatty infiltration
Rugulosin	*/Penicillium islandicum/*	Nephrosis & liver damage
Sterigmatocystin	*/Aspergillus flavus/*	Hepatocarcinogen
	/Aspergillus versicolor/	
Tremorgens	*/Penicillium and Aspergillus/*	
Trichothecenes	*/Fusarium graminearum/*	Cytotoxicity
Vomitoxin (Deoxynivalenol)	*/Fusarium graminearum/*	Vomiting
Zearalenone	*/Fusarium/*	Hyper-estrogenic effect

Source: FAO 1979

Management of Aflatoxin

Methods for managing mycotoxins are largely preventive. They include good agricultural practice and sufficient drying of crops after harvest (Lisker et al., 1991**),** and also the knowledge about fungal sources are needed. The growth of fungi in crops and agricultural products is the main cause of toxin formation and related to the concentration of the toxic substances. There is considerable on-going research on methods to prevent pre- harvest contamination of crops. These approaches include developing host resistance through plant breeding and through enhancement of antifungal genes by genetic engineering, use of bio control agents, and targeting regulatory genes in mycotoxin development (Brown et al., 1998.). As of now, none of these methods has solved the problem. Because mycotoxins are “natural” contaminants of foods, their formation is often unavoidable. Many efforts to address the mycotoxin problem simply involve the diversion of mycotoxin-contaminated commodities from the food supply through government screening and regulation programs. In summary, they can be divided into plant breeding, good agronomic practices and detoxification. Toxin-producing fungi may invade at pre-harvesting period, harvest-time, during post-harvest handling and in storage. According to the site where fungi infest grains, toxinogenic fungi can be divided into three groups: (a) field fungi; (b) storage fungi; and (c) advanced deterioration fungi. The first category includes species of plant pathogenic fungi, namely, genus *Fusarium*, e.g. *F. moniliforme, F roseus, F. tricinctum and F. nivale.* The "storage fungi" are principally the general *Aspergillius and Penicillium,* e.g. *A. flavus and A. parasiticus*. The "advanced deterioration fungi" normally do not infest intact grains but easily attack damaged ones and requires high moisure content. The examples of the third group are *A. clavatus, A. fumigatus, Chaetomium, Scopulariopsis, Rhizopus, Mucor, and Absidia*. Other agronomic approaches such as avoiding water stress, minimizing insect infestation and reducing inoculum potential have been suggested and are effective when the farmers can implement such practices. Following good agricultural practices during both pre-harvest and post-harvest conditions would, minimize the problem of contamination by mycotoxins such as aflatoxins, ochratoxin and trichothecene mycotoxins. The prevention and management of mycotoxins in our environment is a big task. In general, prevention of the contamination of fungi and their mycotoxins in agricultural commodities can be divided into these following three levels:

1. Primary prevention

The step of prevention should be initially carried out before the fungal infestation and mycotoxin contamination. This level of prevention is the most important and effective plan for reducing fungal growth and mycotoxin production. Several practices have been recommended to keep the conditions unfavourable for any fungal growth. These include:

* development of fungal resistant varieties of growing plants;
* control field infection by fungi of planting crops;
* making schedule for suitable pre-harvest, harvest and post-harvest;
* lowering moisture content of plant seeds, after post harvest and during storage;
* Store commodities at low temperature whenever possible;
* Using fungicides and preservatives against fungal growth;

* Control insect infestation in stored bulk grains with appropriate insecticides

2. Secondary prevention

This level of prevention is required if the invasion of some fungi begins in commodities at early phase. The existing toxigenic-fungi should be eliminated or its growth to be stopped to prevent further deterioration and mycotoxin contamination. Several measures are suggested as follows

* Stop growth of infested fungi by re-drying the products;
* Removal of contaminated seeds;
* Inactivation or detoxification of mycotoxins contaminated
* Protect stored products from any conditions which favour continuing fungal growth

3. Tertiary prevention

Once the products are heavily infested by toxic fungi, the primary and secondary preventions would not be then feasible. Any action would not be as effective as the practices mentioned above, since it will be quite late to completely stop toxic fungi and reduce their toxin formation. However, some measures should be done to prevent the transfer of fungi and their health hazardous toxins highly contaminated in products into our daily foods and environment. For example, peanut oil extracted from poor-graded peanut seeds always contains very high levels of aflatoxins and the oil-soluble toxin has to be eliminated by absorption and alkalinization during oil refining process. Only a few practices are recommended:

* Complete destruction of the contaminated products;
* Detoxification or destruction of mycotoxins to the minimal level

Since aflatoxin is the most well-known mycotoxin ever thoroughly studied, its prevention and control has been most successfully practiced in various countries, therefore, this paper will focus on such practices in certain detail for the prevention and control of aflatoxins/mycotoxin contamination. Successful development will bring a great impact for the increased production of crops and safe and nutritious foods around the world. A number of researchers have been working on *A. flavus*-resistant or tolerant varieties of corn (Widstrom et al 1984; Zuber et al., 1978) and peanut (Mixon et al., 1973; Mixon et al., 1981; Davidson et al., 1981). It has been clear that the fungal-resistance of each variety is genotypic. However, the resistance to invasion of *A. flavus* has been attributed to several biochemical, environmental and physical factors. Uncontrollable factors could bring the failure in the utilization of selected fungal-resistant variety, as shown by laboratory screening, in the field. Davis and his co-workers (Davis et al., 1984) reported the survey and comparison of aflatoxin contamination in up to 215 corn hybrids grown in Alabama, USA during 1976-81. Unfortunately, they could not find any hybrid tested resistant to aflatoxin formation. They were convinced that significant aflatoxin levels generally accompanied stress caused by high temperature, low rainfall, low moisture-holding capacity of sandy soils and insect infestation. Differential pathogenic capacities of various toxigenic strains of A. flavus have been observed (Jones et al., 1981). Some strains would require physical damage for their infestation and others would not. The association of mycotoxin production and physical damage to grain and drought during grain ripening indicates that *Aspergillus spp*. is weak pathogens. During long grain storage, the biochemical activity of grain is much reduced, while invasion of storage fungi and mycotoxin contamination would increase. More data is needed on the biochemistry and pathogenesis of toxigenic fungi to understand and evaluate their genotype. The germination and viability of maize seeds could be affected by attack of *Aspergillus* and *Penicillium* species and their fungal infestation have been found to be different among maize genotypes (Sanders et al., 1981; Sauer et al., 1968). Similarly, genotypes of peanut and biochemical properties of its seed such as tannin content (Mixon et al., 1971), thin pericarp (Rao et al., 1967), small amount of cuticular wax (La Prade et al., 1973) and chemical composition of the pericarps and embryos (Lindsey et al., 1975) have been shown to inhibit fungal invasion by *A. flavus* and aflatoxin formation. Recently, antifungal enzymes, chitinase (Roberts et al., 1986) and B-1, 3-glucanase (Nelson et al., 1969) found in a number of plant seeds, may act as defence against pathogenic fungi, since chitin and glucan are major polymeric components of many fungal cell walls. Such polysaccharides in fungal cell wall could be enzymically hydrolysed into smaller products resulting in the damage or killing of fungal mycelia or spores. The role of these enzymes for genotype evaluation is now being studied. It is foreseen that seeds rich in such antifungal enzymes likely resist the infestation of fungi. If so, the seeds for breeding would be easily screened out and used a stock one. Even there are many technical problems in searching for the "super" plant against pathogenicity, the development of fungal-resistant plant varieties utilizing genetic resistance to mycotoxin contamination is still possible and encouraged

* Drying seeds and commodities to the safe moisture levels (<9% f peanut kernel, and < 13.5% for corn).
* maintenance of the container or warehouse at low temperature and humidity.
* keep out insects and pests from the storage
* Gamma-irradiation of large-scale commodities (WHO, 1988).
* Chemical treatment with synthetic fungicides
* organic acids: acetic acid (Buchanan et al., 1979), propionic acid and butyric acid (Gosh et al., 1985), malonic acid (Megalla et al., 1982), benzoic acid (Uraih et al .,1981 ;Chipley et al., 1980), sorbic acid (Youssef et al., 1984), lactic acid (Youssef et al., 1984), citric acid (Reiss et al., 1979) and their sodium salts.
* sodium chloride (El-Gazzzar et al., 1969)

* Benzoic acid derivatives (Davis and Diener, 1967): Onitrobenzoate, O-aminobenzoate paminobenzoate, benzocain (ethly aminobenzoate), ethyl benzoatmethyl benzoate and aspirin (O-acetoxy benzoic acid).
* potassium sulfite and potassium fluoride (Davis et al., 1967)
* dichorvos (Yao et al., 1967)
* fumigant: ammonia and phosphine (Vandergraft et al., 1975).
* treatment with natural products from plants or herbs.
* allicin and related substances from garlic and onion extracts (Appleton et al., 1977)
* chitosan or derivative of chitin isolated from crustacean shells (Cuero et al., 1988)
* cinnamon extract: trans-cinnamic acid, trans-cinnamaldehyde, and ferulic acid (phydroxy-3-methyl cinnamic acid) (Bullerman et al., 1977)
* clove oil (Bullerman et al., 1977)
* other herbs: thyme, star anise seeds (Hitokoto et al., 1978), black and white pepper (Madhyastha et al 1984). plumbago indica (Unpublished data).

Decontamination of Mycotoxins

Contaminated mycotoxins in foods and feeds should be removed inactivated or detoxified by physical, chemical and biological mean depending on the conditions. However, the treatment has its own limitations, since the treated products should be health safe from the chemicals used and their essential nutritive value should not be deteriorated. The following methods are suggested to be applied for effective decontamination of some mycotoxins. Physically, fungi-contaminated seeds can be removed by hand picking or photoelectric detecting machines. The method would consume time and labour or expensive. Organic solvents (chloroform, acetone, hexane and methanol) have been used to extract aflatoxins for agricultural products, but mainly in vegetable oil refining process (Vorster et al., 1985). Heating and cooking under pressure can destroy nearly 70% of aflatoxin in rice compared to under atmospheric pressure only 50% destroyed (Coomes et al., 1966).Dry and oil roastings can reduce about 50-70% of aflatoxin B1 (Feuell et al., 1966). We could show that only about 10% of total 1242 parts per billion (ppb) of aflatoxin B decreased in naturally contaminated peanut by heating at up to 100℃ (Songpan ,1989). Since aflatoxin resist to higher temperature up to 260℃, long-time cooking and overheating would destruct essential vitamins and amino acids in treated foods. Ionizing radiation such as gamma-rays can stop growth of food spoilage organisms, including bacteria, moulds and yeasts. It also inactivates pathogenic organisms including parasitic worms and insect pests. It has been reported that gamma irradiation (5-10 M-rad) caused reduction of aflatoxin (Sommer et al., 1969). The irradiation, however, could not completely destroy the toxin and its mutagenicity. In our laboratory, only about 30% of total 600 parts per billion (ppb) at aflatoxin B1, either pure toxin or in contaminated peanut, was destroyed by 1 and 5 Mrad or gamma irradiation (Chipley et al., 1980). The treatment combination of gamma irradiation and ammoniation should be therefore attempted for more aflatoxin decontamination. Chemical treatment has been used as the most effective means for the removal of mycotoxins from contaminated commodities. The method should be sure that the detoxification system is capable of converting the toxin to a nontoxic derivative (s) without deleterious change in the raw product. Mutagenicity of the treated products should be assessed. The toxicity may be checked by feeding animals including bouts, egg embryos, chicken, ducklings and rats. Many common chemicals have been brought to test the effectiveness in detoxification of aflatoxin. These chemicals include the followings:

* Acetic acid (C_2H_5OH) (Pons et al., 1981)
* Ammonia gas (NH_3) or NH_4OH or ammonium salts, 3-5% (Brekke et al., 1977)
* Calcium hydroxide ($Ca(OH)_2$) (Codifier et al.,1976)
* Formaldehyde (Codifier et al 1976; Mann et al., 1970)
* Hydrogen peroxide (H_2O_2 (Spreenivasamurthy et al ., 1967)
* Methylamine (CH_3-NH_2) (Park et al., 1983)
* Ozone gas (0_3) (Dwaratanath et al., 1968)
* Phosphoric acid (H_3PO_4) (Mann et al., 1970)
* Phosphine gas (PH_3),
* Sodium bicarbonate ($NaHCO_3$) (Mashaly et al., 1983)
* Sodium bisulphite ($NaHSO_3$) (Moerch et al., 1980)
* Sodium bisulphite (NaOH) (Mashaly et al., 1983; Moerch et al., 1980)
* Sodium hypochlorite (NaOCl) (Yang et al., 1972)

The chemical reactions of detoxification of aflatoxin are primary addition of the double bond of the furan ring and oxidation involving phenol formation and opening of the lactone ring. In the presence of acid, aflatoxins B. and G. will be converted into their 2-hydroxy derivatives, aflatoxins B2a and G2a respectively. The molecule can be similarly destroyed by alkaline condition using ammonia, sodium hydroxide and sodium bicarbonate. These toxins are patulin, penicillin acid, citreoviridin, citrinin, cyclochlorotin, ochratoxin A, rubratoxin, trichothecenes and zearalenone. Certain conditions such as moisture content, heat, ultraviolet or gamma irradiation, sunlight and pressure at different treatment-periods have been simultaneously combined with the chemicals for the enhancement of detoxification blbdrbondte (3%) on AFB1 in peanut. Inactivation methods can be achieved by mixing, packing, fumigation and immersion with the chemical used.

RECOMMENDATIONS

Careful control of mycotoxins should be started and administered by the government of each country through ministries and organizations such as the Ministry of Health, the Ministry of Agriculture, Food and Drug Administration, National Environment Committee Board and Consumer Protection Committee Board.

The control program may be set up by a special administrative committee and the legislative body who regulate the national policy of food safety and the maximum tolerance limits for mycotoxins. Farmers, middlemen, food and feed factories and exporters should be well educated about mycotoxins and encouraged to prevent and control the contamination of microflora and their health-hazardous mycotoxins in their commodities as much as possible. International cooperation for the mycotoxin regulation in trading products or commodities is also needed. The countries should establish quality control limits for certain commodities intended for export or import. The producer countries would be stimulated to be aware of mycotoxin contamination in their exported susceptible commodities. For mixed feed and complete feed for cattle, sheep and goats. International organizations such as FAO, WHO and UNEP in the UN system are engaged in providing essential information on various aspects of prevention and control of mycotoxin problems to all the countries. Guidelines for international trade include: a) procedure of sampling and analysis, b) surveillance and food control inspection systems, c) use of 20 parts per billion (ppb) contaminated produce in feeding of different animals, d) protocols for detoxification and the quality control of the products. Conferences, symposiums, trainings and workshops on current information of mycotoxins should be promoted. Low-cost technology for assessment, prevention and control of environmental mycotoxins could be then transferred from developed countries to developing ones.

OUTCOME OF THE REVIEW /CONCLUSION

Mycotoxin management costs are incurred by both producers and the governments to prevent mycotoxins from becoming a human and animal health threat. Aflatoxin is the mycotoxin generating the greatest losses and the highest management costs due to its extremely high toxicity on a unit basis, and its long history of stringent regulation. The peanut, corn, cottonseed, and tree nut industries all recognize losses associated with meeting regulatory levels. The costs are inversely related to the regulatory level that must be met, and lower concentration allowances will increase the costs of crop management. Several effective ways for the management of mycotoxin contamination in agriculture have been stressed. The methods include biological control and physical and chemical treatments. Selection of fungal resistant hybrids of crops are recommended and further experimented. Pre-harvesting preparation of the field and environments should be aware of. Drying of commodities after post harvest is the most economical and effective means for farmers or laymen, but sometimes is not suitable during rainy season or wet condition. Thermal treatment or gamma irradiation is not effective or practically used by villagers. Chemical treatments such as alkalinization and ammoniation are well-recognized and industrially used. Some modifications of the application of effective chemicals to the detoxification of mycotoxins should be developed. International cooperation through authorized organizations should be promoted and supported, aiming the benefits for the economics and health of people of all the nations. In conclusion, One strategy to manage mycotoxin contamination to lower both the health risks and the economic costs associated with mycotoxins is to instruct food producers and handlers on strategies to minimize mycotoxin contamination, and to encourage the adoption of process-based guidelines such as Good Agricultural Practices (GAPs) before harvest and good manufacturing practices (GMPs) after harvest. These strategies would minimize risk throughout the production, handling, and processing chain, and can complement product standards.

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