

A Review of Mycotoxins and Food Storage

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ABSTRACT

Mycotoxins are secondary metabolites produced by fungi; they are toxic to vertebrates and other animal groups in low concentrations. Mycotoxins are hard to define and are also very difficult to classify. Mycotoxins are often arranged by physicians depending on what organ they effect. Mycotoxins can be categorized as nephrotoxins, hepatoxins, immunotoxins, neurotoxins. They can also be classified based on the species of microbes (fungi) producing them such as: citrinin produced by *Penicillium citrinum*, fumonisins by member of the family is fumonisin, ochratoxin by *Aspergillus ochraceus*, patulin by *Penicillium patulum*. The low water requirement by most yeast and mold makes them to be invariably in association with most cereals, grains, seed foods, nuts and nut products. They are also found in association with milk and milk products, vegetables, herbal medicines and animal feeds. Mycotoxins presence in food can result in some health impacts such as; nephrotoxicity, hepatotoxicity, neurotoxicity and immunotoxicity.

1. Introduction

Mycotoxins are secondary metabolites produced by fungi; they are toxic to vertebrates and other animal groups in low concentrations (Anaso et al., 2021a). Other low-molecular-weight fungal metabolites such as ethanol that are toxic only in high concentrations are not considered mycotoxins (Bennett, 1987: Anaso et al., 2021b; Anaso, 2023b). Mushroom poisons are fungal metabolites that can cause disease and death in humans and other animals; they are rather arbitrarily excluded from discussions of mycotoxicology (Anaso, 2023a). Molds make mycotoxins; mushrooms and other macroscopic fungi make mushroom poisons (Anaso et al., 2024b). The distinction between a mycotoxin and a mushroom poison is based not only on the size of the producing fungus, but also on human intention (Anaso et al., 2024c: Anaso, 2024). Mycotoxin exposure is almost always accidental. In contrast, with the exception of the victims of a few mycologically accomplished murderers, mushroom poisons are usually ingested by amateur mushroom hunters who have collected, cooked, and eaten what was mis-identified as a delectable species (Moss, 1996).

Mycotoxins are hard to define and are also very difficult to classify. Mycotoxins have diverse chemical structures, biosynthetic origins, myriad biological effects, and produce numerous different fungal species. Classification generally reflects the training of the categorizer and does not adhere to and set system. Mycotoxins are often arranged by physicians depending on what organ they affect. Mycotoxins can be categorized as nephrotoxins, hepatoxins, immunotoxins, neurotoxins. Generic groups created by cell biologist are teratogens, mutagens, allergens, and carcinogens. Organic chemists have attempted to classify them by their chemical structures; biochemists according to their biosynthetic origins (polyketides, amino acid-derived) physicians by the illnesses they cause, and mycologists by the fungi that produce them (*Aspergillus* toxins, *Penicillium* toxins) (Anaso and Alagbe, 2025: Anaso and Al-Hassan, 2025). None of these classifications is entirely satisfactory. Aflatoxin, for example, is a hepatotoxic, mutagenic, carcinogenic, difuran-containing, polyketide-derived *Aspergillus* toxin. Zearalenone is a *Fusarium* metabolite with potent estrogenic activity; hence, in addition to being called (probably erroneously) a mycotoxin, it also has been labeled a phytoestrogen, a mycoestrogen, and a growth promotant (Bennett, 2003: Anaso et al., 2024a).

1.1 Background information

Mycotoxicology is the branch of mycology that focuses on analyzing and studying the toxins produced by fungus, known as Mycotoxins. As many microorganisms, fungus produce toxins as a response of biological stress in the environment, like lower nutrients or competitions for those available, conditions that trigger the secondary metabolism. Under this secondary path the

fungus produces a wide array of compounds, usually enzymes, produced them in order to gain some level of advantage, like incrementing the efficiency of metabolic process to gain more energy from less food, or attacking another microorganism and being able to use their remains as a food source (Anaso et., 2021b).

Mycotoxicology is important in industrial processes that involves the production of food (for human or animal consumption) via the use of fungus and yeast, or with machinery in contact of these microorganisms because many of these enzymes manage to survive sterilization and can be harmful for human and animals. Mycotoxin contamination of food stuffs is a worldwide problem and a major health threat for humans and animals that cause significant economic losses in both developing and developed countries (Anaso et al., 2024d). Besides, mycotoxin contaminations of agricultural crops pose significant economic losses to both crop producer and handlers who have to give market discounts for the contaminated products. In cases of severely contaminated crops, they have to dispose of the product. Other economic losses related to mycotoxin contamination of foodstuffs are loss of business and product recall (Herrman et al., 2002).

2.0 Types of Mycotoxins

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2.1 Citrinin

Citrinin was first isolated from *Penicillium citrinum* prior to World War II; subsequently, it was identified in over a dozen species of *Penicillium* and several species of *Aspergillus* (e.g., *Aspergillus terreus* and *Aspergillus niveus*), including certain strains of *Penicillium camemberti* (used to produce cheese) and *Aspergillus oryzae* (used to produce sake, miso, and soy sauce) (Manabe, 2001). More recently, citrinin has also been isolated from *Monascus ruber* and *Monascus purpureus*, industrial species used to produce red pigments (Blanc et al., 1996).

2.2 Aflatoxins

The aflatoxins were isolated and characterized after the death of more than 100,000 turkey poult (turkey X disease) was traced to the consumption of a mold-contaminated peanut meal (Goldblatt, 2008). The four major aflatoxins are called B1, B2, G1, and G2 based on their fluorescence under UV light (blue or green) and relative chromatographic mobility during thin-layer chromatography. Aflatoxin B1 is the most potent natural carcinogen known (Squire, 1981) and is usually the major aflatoxin produced by toxigenic strains. It is also the best studied: in a large percentage of the papers published, the term aflatoxin can be construed to mean aflatoxin B1. However, well over a dozen other aflatoxins (e.g., P1, Q1, B2a, and G2a) have been described, especially as mammalian biotransformation products of the major metabolites. The classic book *Aflatoxin: Scientific Background, Control, and Implications*, published in 1969, are still a valuable resource for reviewing the history, chemistry, toxicology, and agricultural implications of aflatoxin research.

2.3 Fumonisin

Fumonisin were first described and characterized in 1988. The most abundantly produced B1. They are thought to be synthesized by condensation of the amino acid alanine into an acetate-derived precursor (Sweeney and Debson, 1999). Fumonisin are produced by a number of *Fusarium* species, notably *Fusarium verticillioides* (formerly *Fusarium moniliforme* = *Gibberella fujikuroi*), *Fusarium proliferatum*, and *Fusarium nygamai*, as well as *Alternaria alternata* lycopersici. These fungi are taxonomically challenging, with a complex and rapidly changing nomenclature which has perplexed many nonmycologists and some mycologists, too (Marasas et al., 1984 and Leslie, 1996). The major species of economic importance is *Fusarium verticillioides*, which grows as a corn endophyte in both vegetative and reproductive tissues, often without causing disease symptoms in the plant. However, when weather conditions, insect damage, and the appropriate fungal and plant genotype are present, it can cause seedling blight, stalk rot, and ear rot (Nelson et al., 1993). *Fusarium verticillioides* is present in virtually all corn samples. Most strains do not produce the toxin, so the presence of the fungus does not necessarily mean that fumonisin is also present. Although it is phytotoxic, fumonisin B1 is not required for plant pathogenesis (Marasas, 1996; Desjardins and Plattner, 2000).

2.4 Ochratoxin

Ochratoxin A was discovered as a metabolite of *Aspergillus ochraceus* in 1965 during a large screen of fungal metabolites that was designed specifically to identify new mycotoxins. Shortly thereafter, it was isolated from a commercial corn sample in the United States and recognized as a potent nephrotoxin. Members of the ochratoxin family have been found as metabolites of many different species of *Aspergillus*, including *Aspergillus alliaceus*, *Aspergillus auricomus*, *Aspergillus carbonarius*, *Aspergillus glaucus*, *Aspergillus melleus*, and *Aspergillus niger* (Bayman et al., 2002). Because *Aspergillus niger* is used widely in the production of enzymes and citric acid for human consumption, it is important to ensure that industrial strains are nonproducers. Although some early reports implicated several *Penicillium* species, it is now thought that *Penicillium verrucosum*, a common contaminant of barley, is the only confirmed ochratoxin producer in this genus. Nevertheless, many mycotoxin reviews reiterate erroneous species lists. (Teren et al., 2006).

2.5 Patulin

Patulin, 4-hydroxy-4H-furo[3,2c]pyran-2(6H)-one, is produced by many different molds but was first isolated as an antimicrobial active principle during the 1940s from *Penicillium patulum* (later called *Penicillium urticae*, now *Penicillium griseofulvum*). The same metabolite was also isolated from other species and given the names clavacin, claviformin, expansin, mycoin and penicidin. A number of early studies were directed towards harnessing its antibiotic activity. For example, it was tested as both a nose and throat spray for treating the common cold and as an ointment for treating fungal skin infections (Cieger et al., 2001). However, during the 1950s and 1960s, it became apparent that, in addition to its antibacterial, antiviral, and antiprotozoal activity, patulin was toxic to both plants and animals, precluding its clinical use as an antibiotic. During the 1960s, patulin was reclassified as a mycotoxin.

2.6 Trichothecenes

The trichothecenes constitute a family of more than sixty sesquiterpenoid metabolites produced by a number of fungal genera, including *Fusarium*, *Myrothecium*, *Phomopsis*, *Stachybotrys*, *Trichoderma*, *Trichothecium*, and others. The term trichothecene is derived from trichothecin, which was the one of the first members of the family identified. All trichothecenes contain a common 12,13-epoxytrichothene skeleton and an olefinic bond with various side chain substitutions. They are commonly found as food and feed contaminants, and consumption of these mycotoxins can result in alimentary hemorrhage and vomiting; direct contact causes dermatitis (Marasas, 2000).

2.7 Zearalenone

Zearalenone (6-[10-hydroxy-6-oxo-trans-1-undecenyl]-B-resorcylic acid lactone), a secondary metabolite from *Fusarium graminearum* (teleomorph *Gibberella zeae*) was given the trivial name zearalenone as a combination of *G. zeae*, resorcylic acid lactone, -ene (for the presence of the C-1' to C-2 double bond), and -one, for the C-6' ketone. Almost simultaneously, a second group isolated, crystallized, and studied the metabolic properties of the same compound and named it F-2 (Christensen, 2007). Much of the early literature uses zearalenone and F-2 as synonyms; the family of analogues are known as zearalenones and F-2 toxins, respectively. Perhaps because the original work on these fungal macrolides coincided with the discovery of aflatoxins, chapters on zearalenone have become a regular fixture in monographs on mycotoxins. Nevertheless, the word toxin is almost certainly a misnomer because zearalenone, while biologically potent, is hardly toxic; rather, it sufficiently resembles 17 β -estradiol, the principal hormone produced by the human ovary, to allow it to bind to estrogen receptors in mammalian target cells. Zearalenone is better classified as a nonsteroidal estrogen or mycoestrogen (Anaso et al., 2023). Sometimes it is called a phytoestrogen. For the structure-activity relationships of zearalenone and its analogues (Shier, 2004).

3.0 Mycotoxins Association and Food Storage

Back from history, it has been observed that the ubiquitous nature of microorganisms makes them to be invariably in association with food. Likewise storage foods most especially cereals and grains which are stored in an unsterile environment or microbe friendly environment are more susceptible to be contaminated with mycotoxins (Anaso et al., 2024d; Anaso et al., 2025). The followings are the examples of foods that are likely to be contaminated with mycotoxins.

3.1 Cereals and grains

Rice is the main product and staple food in many country including Malaysia. Corn, wheat, and barley are not staple food grains in this countries and are totally imported from Argentina, China, Indonesia, and Thailand (Warr et al., 2008). In a survey on stored paddies, rice and rice flour samples were contaminated with aflotoxins (Mardi, 1992). However, aflotoxin levels in the positive samples were lower than 4 ng/g. *Aspergillus flavus* was also isolated from some of the aflotoxin-negative samples. Contamination of wheat flour from retail markets with AFs has been reported earlier (Abdullah et al., 1998).

The level of AFs in wheat flour samples was in the range of 11.25 to 436.25 ng/g. Abdullah et al., (1998) conducted a survey on fungal colonies in starch-based foods from retail outlets in Malaysia. Aflatoxigenic colonies of *Aspergillus* were detected in wheat flour (20%), glutinous rice grains (4%), ordinary rice grains (4%), and glutinous rice flour (2%). Ordinary rice samples

were contaminated with AFG1 (2.4%) and AFG2 (3.6%). Level of AFs in the positive samples collected from private homes ranged from 3.69 to 77.50 ng/g. About 1.2% of wheat flour samples was contaminated with AFB1 (25.62 ng/g), and 4.8% with AFB2 (11.25 to 252.50 ng/g), 3.6% with AFG1 (25.00 to 289.38 ng/g), and 13.25% with AFG2 (16.25 to 436.25 ng/kg). Higher incidence of AF contamination in wheat flour can be due to the following factors: first, presence of aflatoxin-producing *Aspergillus* spp. is more often seen in wheat flour than ordinary rice, and second, there are longer storage periods for wheat flour compared to other grain flours. (Abdullah et al., 1998) concluded that aflatoxin contamination occurred at the consumer level since the percentage of contaminated samples was higher at private homes compared to retail markets.

3.2 Nuts and nut products

In some developed countries such as Malaysia, peanuts are a common dietary staple consumed in the raw, roasted, or baked form. Peanuts and peanut products have the highest consumption among the nuts produced in Malaysia. Penang adults consume an average of 0.77 grams of total nuts (including peanuts) per day (Leong et al., 2010). Raw shelled peanuts can be found in almost all retailed outlets throughout the country and they are widely used as an ingredient in a variety of popular foods and dishes. Peanuts in Malaysia are partially supplied by local production; however, the majority are imported from India, Vietnam, and China. The occurrence of AF in nuts and peanut has been proven (Abdulkadar et al., 2004). Aflatoxin contamination of groundnut and groundnut oil was reported by Chong and Beng, (1995). Consumption of such contaminated commodities exposes humans and animals to different levels of AF from nanograms to micrograms per day. Due to consumption of AF-contaminated groundnuts, an outbreak in pig farms in Melaka was reported in 1998 (Abdulkadar et al., 2004).

In many countries, a large variety of spices is used as main ingredients in daily cooking. Malaysia is one of the main producers of spices (especially peppers) in the world and black and white peppers are the major export commodities. However, due to tropical climate conditions, mycotoxin contamination almost always occurs during harvesting, post harvesting, and storage. Therefore, it is necessary to conduct regular monitoring on mycotoxin contaminations in spices. In an early screening study by Mardi in 1984 to 1985, black and white pepper samples from the Pepper Marketing Board (PMB) in the state of Sarawak were analyzed. All pepper samples were positive for AFs. According to the report, aflatoxin contamination of pepper is due to traditional processing and storage methods. However, to reduce the contamination and microbial loads, pepper intended for export is being re cleaned and reprocessed. Later in 1987, Mardi surveyed 19 different types of commonly-used spices including dry and wet spices. All samples were contaminated with AFs. According to Mardi, (1987) this is probably due to unsuitable storage conditions at retail outlets where the products are kept for long periods. Jalili et al., (2009) screened imported and locally produced pepper products from Malaysian markets and found 55.5% of all samples contaminated with AFs (low level of contamination 0.1 to 4.9 ng/g). AFB1 was the highest among other AFs. White peppers were less contaminated compared to black pepper samples collected from the same farm, probably due to the processing effect. In white pepper production there is an extra process of shell removal, which can reduce mycotoxin contamination (Jalili et al., 2009). In the study by Reddy et al., (2011), 93.3% of analyzed spices were contaminated with AFB1 at 0.58 to 4.64 ng/g. All chili and pepper samples were contaminated with AFB1. Cumin powders contained the highest levels of AFB1 ranging from 1.89 to 4.64 ng/g (Reddy et al., 2011).

The latest study by Jalili and Jinap, (2012a) on AFs in several chilli samples from open markets and supermarkets in Malaysia showed that 65% of all samples taken were contaminated with total AF levels in the range of 0.2 to 79.7 ng/g. AFB1 was the highest as compared to the other examined AFs. Higher levels of AFs were observed in samples collected from open markets (Jalili and Jinap 2012a). Jalili et al., (2010; 2012a) detected OTA in 81.25% of chili samples from Malaysian market ranging from 0.2 to 101.2 ng/g (Jalili et al., 2010; Jalili and Jinap 2012a). About 95% of samples from the open market and 45% from supermarkets were contaminated with OTA. Higher contamination in samples from open markets can be due to long period and improper storage conditions of spices. Their results also indicated that 16.3% of the samples were contaminated with OTA more than 10 ng/g. In another study, Jalili et al., (2012b) examined OTA in commercial peppers which consisted of imported and local black and white pepper in powder and seed form. About 47.5% of samples were contaminated with OTA at levels of 0.15 to 13.58 ng/g, and 33.3% of them exceeded the maximum limit of 5 ng/g (Jalili and Jinap 2012b). However, very low concentrations of OTA were detected in prepacked peppers. Contamination was higher in black pepper compared to white pepper due to different processing methods. In the production of white pepper, peppercorn shells are removed which reduce mycotoxin contaminants.

3.3 Vegetables and fruits

In an intensive study on occurrences of *Fusarium* species in plants from Peninsular Malaysia during the period 1981 to 1986, more than 1000 isolates of *Fusarium* were obtained from rice, potato, water melon, and chilli (Salleh and Strange 1988). Three species of *F. proliferatum*, *F. nygamai*, and *F. longipes* were identified on plants. They also reported the association of *F. solani*

and *F. oxysporum* var. *redolens* with human diseases. A survey on occurrence of *Fusarium* species on vegetable fruits from markets in Penang Island reported 6 species namely, *F. semitectum*, *F. oxysporum*, *F. subglutinans*, *F. proliferatum*, *F. solani*, and *F. equiseti* (Nurulhuda et al., 2009). The most common species isolated from cucumber (*Cucumis sativus*), tomato (*Lycopersicon esculentum*), okra (*Hibiscus esculentus*), loofah (*Luffa acutangula*), bitter melon (*Momordica charantia*), brinjal (*Solanum melongena*), and fresh red chilli (*Capsicum annuum*) were *F. semitectum* (33%) followed by *F. oxysporum* (27%) and *F. solani* (25%). Since all the 6 identified species are able to produce mycotoxins, they suggested that vegetable fruits could pose health hazard. Latiffah et al., (2007) isolated different *Fusarium* species from crops cultivated in Penang. They isolated *F. solani* species on lettuce, papaya, starfruit, cabbage, paddy, banana, dragon fruit, longan, and limau kasturi. *F. equiseti* was reported in lettuce and dragon fruit. *F. semitectum* was isolated on lettuce and paddy. In a survey on *Fusarium* species associated with wet market potatoes in Malaysia, 65 *Fusarium* strains were isolated and identified from samples collected from different regions in Malaysia. All of the 65 isolates belong to *F. solani* and *F. oxysporum* species (Chehri et al., 2011). Manshor et al., (2012) also reported occurrence of *F. solani* on grape and loofah (petola) fruits grown in highland areas in Malaysia.

3.4 Oil seeds

The single study on mycotoxin contamination in oilseeds (including sunflower and sesame) from Malaysia showed that 82.1% of samples were contaminated with AFB1. However, the extent of contamination was not too high, varying from 0.54 to 5.33 ng/g (Reddy et al., 2011; Anaso et al., 2024c).

3.5 Cocoa bean

In 1986, Mardi surveyed dried cocoa beans from the states of Selangor and Perak. About 31% of the samples collected were contaminated with AFs. Samples with the highest contamination had high moisture contents in the range of 11% to 13.8% (Mardi, 1986).

3.6 Milk and eggs

In the survey by Abidin and Mat Isa (1992), samples of locally produced fresh milk and eggs from wet markets in the states of Selangor, Negeri, Sembilan, and Melaka were examined. Only 1.7% of fresh milk samples from Selangor contained AFM1 at 0.24 ng/g. About 20% of all eggs were contaminated with AFs at 0.16 to 0.41 ng/g.

3.7 Herbal medicines

Traditional herbal medicines called jamau and makjun that commonly consumed in Malaysia were screened for AFs. The incidence of AFB1, AFB2, AFG1, and AFG2 were 70%, 61%, 30%, and 4%, correspondingly. However, the extent of total AF contamination was considerably low at 0.03 to 1.57 ng/g (Ali et al., 2005).

3.8 Feeds

Animal feed are both imported and locally produced in Malaysia. Most of the raw ingredients (including cereal grains, soybean meal, and corn gluten meal) are imported from Thailand, China, India, Argentina, U.S.A., Australia, and Canada. Due to improper storage conditions during production and transportation, there are always reports on feed contamination by mycotoxins. A survey conducted by Mardi from 1981 to 1984 showed that more than 70% of feed samples were contaminated by AFs (Ali, 2000). Muniandy (1989) reported AFB1 levels of 5 to 400 ng/g in 10% of analyzed animal feed from Malaysia. Maize is the most commonly used feed ingredient in Asian countries. In the study on mycotoxin contamination in animal feeds from Asia, high levels of AFB1 (106 ng/g) were reported in maize samples from Malaysia (Binder et al., 2007). Lee-Jiuan and Li-Mien (2006) surveyed the occurrence of mycotoxins in feedstuffs from Asian countries. They reported corn sample from Malaysia with high mycotoxins contamination including OTA, Afs, ZEN, and FEM. The samples showed OTA levels as high as 143 µg/g. In another survey on imported poultry feed, elevated concentrations of AFB2 were detected in the corn samples, ranging from 0.2 to 101.8 ng/g, which exceed FDA action levels of 20 ng/g (Hong et al., 2010).

4.0 Health Impact of Mycotoxins in Foods

The first warning about aflatoxins in Malaysia was reported after a disease outbreak of 2 pig farms in the state of Melakan (Blanc, 1995). The disease was identified by gross liver damage due to AFs in the feed. The feed had been prepared from imported ingredients including peanut meal and oil cakes. In another incidence, few Chinese children died due to acute hepatic encephalopathy in the state of Perak in 1988. Epidemiologic studies revealed that the incidence was related to the consumption of AF-contaminated Chinese noodle (Lye et al., 1995). The pathological observations showed broad coagulative necrosis of the liver with proliferative ductal/ductular metaplasia of the hepatocytes. Bile stasis, central vein sclerosis, giant cell formation, and steatosis were also observed. Renal and hepatic failure was reported as the ultimate cause of death. Toxicological studies showed a high concentration of AFs in tissues of the victims (Cheng, 1992; Anaso et al., 2024c).

4.1 HACCP and GAP for mycotoxin control and responsibilities of FBOs

In addition to the overall responsibility placed on FBOs by the General Food Law (Directive 178/2002) to supply safe food, FBOs must also ensure that their products comply with the legislative limits for mycotoxins as laid down in Commission Regulation (EC) No 1881/2006 as amended. It is important that FBOs identify CCPs in their processes that may result in mycotoxin contamination, such as mouldy grain or nut products, or storage conditions that may lead to the development of mould. The identification of appropriate CCPs along their process chain will enable them to develop and apply proper HACCP systems which will ensure that there are no unforeseen sources of mycotoxin contamination in their products. While the crop is growing, in the field, adherence to GAP is most important in preventing fungal growth and mycotoxin formation. While GAP is designed to produce healthy, sound plants, rather than specifically to prevent the occurrence of mycotoxins, the controls involved by the application of GAP will normally have this beneficial side-effect.

GAP will typically involve the proper preparation of the land, crop rotation, use of fungus and/or pest resistant cultivars, control of insect damage to the growing crop, control of fungal infection, prevention of stress to the growing crop, e.g. drought, weeds, harvesting at the appropriate time, and correct handling and storage after harvesting. While crops produced according to GAP may be expected to be free of mycotoxins, in some cases specific CCPs are appropriate at the field stage such as removal of visibly damaged material at harvest (which would be susceptible to fungal growth and mycotoxin production) or particular outdoor drying regimes for peanuts immediately post-harvest. Codex Alimentarius has produced a number of Codes of Practice covering GAP for food commodities likely to be contaminated by mycotoxins, while the European Commission has published a Code of Practice for the reduction and prevention of patulin contamination in apple juice and apple juice ingredients in other beverages, and is in the process of finalising a further Commission Recommendation on the prevention and reduction of Fusarium toxins in cereals and cereal products. Storage conditions, such as temperature, water activity (aw), storage time, aeration and pest infestation, contribute to mould growth and mycotoxin production. Moisture content or, more particularly water activity or “free” water, is critical to facilitating the growth of fungi (and potential production of mycotoxins). Since water activity is related to the equilibrium relative humidity, it is a function of temperature, so both moisture content and temperature must be controlled during storage. Pest damage may result in heating and moisture generation, leading to fungal growth and mycotoxin production in localised “hot spots”.

A properly developed and applied HACCP system in food production, together with GAP in crop production, will contribute significantly to the prevention of mycotoxins in food crops. In the case of mycotoxin hazards, application of HACCP will involve development of a Commodity Flow Diagram (CFD) which shows clearly the various steps for the food crop - primary production, storage, transport and processing. From the CFD it is possible to identify the HACCP CCPs, including parameters such as moisture content, temperature, and visible damage that must be monitored. For each CCP identified, the parameter to be measured must be defined and critical limits established. Procedures for monitoring of the CCPs against their critical limits must be established and corrective actions defined to deal with situations where the critical limits are not being achieved, e.g. if a moisture content of 15% is the critical limit for a cereal at a certain storage point (CCP), the corrective action for material exceeding 15% moisture might be removal and checking for mycotoxin content. An effective HACCP system requires verification that application of the CCPs is achieving the goal of appropriate mycotoxin levels in the commodity (ECFFC, 2007).

4.2 Summary

Mycotoxins are poisonous substances produced by fungi during their metabolism. They are toxigenic in nature, so their presence in food connotes contamination of the food samples involved. Their classification varies depending on the organ of the body they are toxic to, and also the species of fungi producing them. Mycotoxins are invariably associated with most cereals, grains and seed foods. This is due to their minimal level of water content. Mycotoxins are produced as the byproducts of fungi as the fungi feed on foods. Mycotoxins presence in the body can result in health impact such; hepatotoxicity, nephrotoxicity, neurotoxicity and immunotoxicity.

4.3 Recommendations

- a) By controlling field infection by fungi of planting crops.
- b) By making schedule for suitable pre- harvest, harvest and post harvest.
- c) By lowering moisture content of plant seeds, after post harvesting and during storage
- d) By storing commodities at low temperature whenever possible.
- e) By using fungicides and preservatives against fungal growth.
- f) By controlling insect infestation in stored bulk grains with approved insecticides.
- g) By pasteurizing milk and dairy product before consumption.
- h) By blanching vegetables or refrigerating fruits, vegetables and eggs.

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