FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

IMPROVING PUBLIC HEALTH AND INTERNATIONAL TRADE THROUGH MYCOTOXIN CONTROL

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INTRODUCTION

Fungi are ubiquitous plant pathogens and are major spoilage agents of foods and feedstuffs. They grow on many foods and feed. The optimal condition for growth differs for several fungi; nevertheless, it has been reported by Ominiski *et al* (1994) that most fungi that are toxigenic do better at temperature between 24 °C - 28 °C and moisture content of the substrate of above 17.5%. Their best substrates are those that provide oil and carbohydrate as an energy source, and proteins, minerals etc. The infection of plants by various fungi not only results in reduction in crop yield and quality, with significant economic losses, but also contamination of grains with poisonous fungal secondary metabolites called mycotoxins. The ingestion of such mycotoxin-contaminated grains by animals and human beings has enormous public health significance, because these toxins can cause diseases in man and animals (Bhat and Vasanthi 2003).

There are over three hundred mycotoxins found in foods, but those that have the most impact on agriculture and public health and consequently economy are aflatoxins (AFs), trichothecenes [e.g. deoxynivalenol (DON), T-2 toxin], fumonisins (FBs), zearalenone (ZEA), patulin (PAT) and ochratoxin A (OTA) (CAST, 2003). The AFs, especially, AFB_1, are potent hepatotoxins and hepatocarcinogens, which were implicated in the death of 215 people in Kenya who consumed highly AF-contaminated maize meals in 2004 (Makun *et al.,* 2012). Trichothecenes are a group of about 150 related compounds that are protein inhibitors with consequent immunosuppressive effects, causing severe damage to the digestive tract and death due to intestinal haemorrhage. The commonest trichothecenes are DON and T-2 toxin (CAST, 2003). Fumonisins, especially fumonisin B_1 (FB_1) cause liver and kidney cancer, and neural tube defects in rodents, leukoencephalomalacia in horses and pulmonary oedema in swine (Marasas *et al.*. 1988). Of major concern is the association

of FB_1 with elevated incidence of human oesphageal cancer in parts of South Africa, North Eastern Iran and China, upper gastrointestinal tract cancer in Northern Italy (Dutton, 1996) and neural tube defects in human babies (Hendricks, 1999). ZEA, an oestrogenic toxin that causes infertility in animals, is associated with outbreaks of precocious pubertal changes in children in Puerto Rico, and has been suggested to have a possible involvement in human cervical cancer (Zinedine *et al.*, 2007). OTA causes kidney and liver impairment in animals (especially pigs) and man (Stoev and Stefan, 2013).

Other emerging mycotoxins that are currently having global attention as reviewed by Njobeh *et al.* (2010) include patulin, moniliformin, penicillic acid, cyclopiazonic acid, ergot alkaloids, sterigmatocystin, ergot alkaloids, citrinin, *Alternaria* toxins and rubratoxins. The IARC (1987) classified sterigmatocystin as group 2B, which means it is carcinogenic in other species and is possibly carcinogenic to humans. Ergot alkaloids may cause strange hallucinations, the feeling of itchy and burning skin, gangrene, loss of hands and feet, and even death. Moniliformin causes cardiac permeability in young rats and ducklings, suggesting a mechanism for inducing Keshan disease in humans. Patulin elicits nausea, vomiting and gastrointestinal disturbances in human being and is classified by the International Agency for Research on Cancer in category 3 as a not classifiable toxic compound regarding its carcinogenicity to humans (IARC, 1993). Citrinin is a nephrotoxin while Cyclopiazonic acid (CPA) causes focal necrosis in most vertebrate inner organ in high concentrations and affects the ducts or organs originating from ducts (Huang *et al.*, 2014). Penicillic acid may cause hepatotoxicity, mutagenotoxicity, genotoxicity, in mice while alternaria mycotoxins affect adversely the liver and kidney and may be a factor in the aetiology of oesophageal cancer in Linxian, China (Liu *et al.* 1992). Rubratoxins are hepatotoxic

mycotoxin found in cereals they have been responsible for outbreak of toxicosis in the U.S (Farlex, 2012).

Historical Background

Although the involvement of fungi and their toxins in causing disease to man and animals dates to the period when the Dead Sea Scrolls were written (Richard, 2007), it seems the evidence for their historic occurrence and impact were not obvious until the Middle Ages, when ergot alkaloids poisoning outbreaks in Europe were responsible for the death of thousands of people. Ergotism, also known as Saint Anthony's Fire, a disease that had its origin in the ingestion of rye and other grains infested with the mould, *Claviceps purpurea* was the first known mycotoxicosis that killed tens of thousands of people in Europe for over 300 years between A.D 900 and 1300. The last epidemics of ergotism were in 1825. However, serious outbreaks did occur in Russia in 1926-7 and in England in 1928; in France in 1951 and Ethiopia in the 1970's resulting in nearly 50 deaths. The disease caused losing of extremities; fingers and limbs." Subsequently, between 1940s and 1950s a lethal human disease caused by *Fusarium* toxins and referred to as 'Alimentary Toxic Aleukia' was reported in Russia (Smith and Moss, 1985). Similarly, in 1938 Japan, *Penicillium* species were responsible for the colouring of rice that erratically led to the fatal human cardiac syndrome called 'yellow rice disease' (Uraguchi and Yamazaki, 1978). The livestock industry was also affected since 1822; the New Zealand sheep industry was devastated by facial eczema, a fungal infection caused by *Pithomyces chartarum.* Other deadly animal syndromes arising from fungal infections and termed differently as equine leukoencephalomalacia (1930s to 1970s in USA), stachybotryotoxicosis (1930s in USSR), red mould diseases (1945-1947 in Japan), and red clover disease, vulvovaginitis and mouldy corn toxicosis (1920s to 1950s in USA) plagued the world (Gbodi and Nwude, 1988). Despite these grave episodes, little attention was paid to fungal diseases. However, in 1960, when the Turkey X disease killed thousands of poultry animals in

Britain (Blount, 1965); the world became fully aware of the potential hazard of mycotoxins and responded to the disaster by a systematic and multidisciplinary approach which led to the discovery of aflatoxins. Following the discovery of aflatoxins, at least three hundred mycotoxins have been shown to occur in nature. But those that pose the greatest risk to human and animal health are aflatoxins (AFs), trichothecenes (deoxynivalenol and T-2 toxin), fumonisins, zearalenone, patulin and ochratoxin A (CAST, 2003) and of these AFs are the most notorious in the food trade because of their high prevalence and severity of health impact and are therefore the most studied.

Prevention and Control of Mycotoxins

The health hazards of mycotoxins translate to food insecurity and financial burden on the national health sector and this is complicated by rejection of export food commodities from international trade which further adversely affect national economy. For these reasons, there are recommended preharvest and postharvest mycotoxin intervention strategies. Preharvest measures include planting fungi resistant cultivars on appropriate soil types and tillage method that reduces fungi inoculum (Jouany *et al.*, 2007). Crop rotation with non-host crops like beets, vegetable interrupts the production of infectious crop debris and survival chance of *Fungi* inoculum for the next season crop. Sowing should be done on dates such that anthesis coincides with the time of release of spore (Eeckhout *et al.*, 2013). Biocontrol techniques which aim at outcompeting toxigenic strains and inhibiting mycotoxins synthesis are effective (IARC, 2015). Management strategies that improve plant nutrition, health and therefore resistance to diseases including fungal infestation such as appropriate use of fertilizer, irrigation, weed and other pesticide control are recommended. Harvesting should be done at maturity and in low moisture conditions (Jouany, 2007) using appropriate harvesting equipment that will result in minimal damage of grains as

damaged grains allow for increased fungal colonization and mycotoxin synthesis; is recommended (CAC, 2016).

Postharvest strategies like removing diseased and damaged kernels before and after storage is effective. Storage under constant low temperature 15°C and "safe" moisture level of <14% profoundly reduce fungi species in agricultural produce (Jouany, 2007). Thermal treatment, irradiation, chemical decontamination and bio-decontamination using microorganisms or enzymes and absorption of mycotoxins in gastrointestinal tract by absorbents are effective in removing mycotoxins from contaminated commodities (EFSA, 2009). The adoption of the principles of Hazard Analysis Critical Control Point (HACCP) into mycotoxin control scheme has led to an integrated approach. The integrated mycotoxin management system, which looks through the farm value chain and identifies all critical points where control can be implemented, has generated better results. While all these methods of prevention, reduction and detoxification of mycotoxins can significantly deplete mycotoxins in foods and feeds, it should be borne in mind that absolute elimination of these toxins from the value chain is impossible.

OUR CONTRIBUTIONS TO MYCOTOXIN MITIGATION

Our contribution to the prevention and control of these menaces to mankind is in identifying and measuring the extent of exposure and risks associated to the presence of mycotoxins in Nigerian food system, and invariably deriving intervention strategies against the food borne hazards.

Risk Assessment of Human Exposure to Mycotoxins in Nigeria

Risk assessment is a scientifically based process consisting of hazard identification, hazard characterization, exposure