Review of Mycotoxins Incidence in Deteriorated Palm Oil and Palm Kernel Cake (PKC)

Mohd Firdaus Othman*, Abdul Niefaizal Abdul Hammid* and Rohaya Mohammed Halim*
*Malaysian Palm Oil Board, 6 Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.
E-mail address: fidos@mpob.gov.my

INTRODUCTION

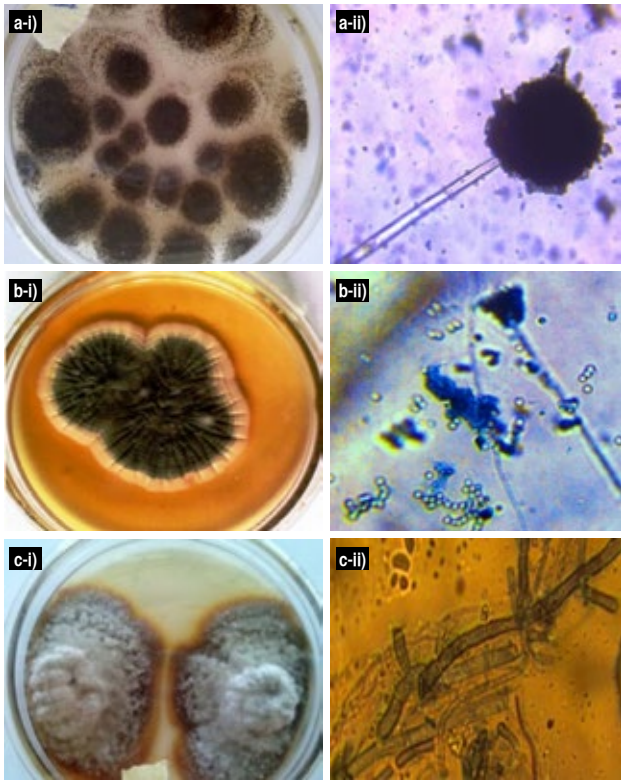
Growth of filamentous fungi in animal feed and food may result in diseases of essential crops and decay of stored foods with possible concomitant production of mycotoxicoses due to mycotoxins as secondary metabolites from moulds (Sorenson, 1999). Mycotoxicoses are diseases caused by mycotoxins, a group of compounds secreted by various fungi as secondary metabolites and excreted into the matrices, which are often intended for human food consumption or animal feedstuffs (Diekman and Green, 1992; Peraica *et al.,* 1999; Cigić and Prosen, 2009).

Mycotoxicoses caused variety of adverse effects in human, from allergic responses to immunosuppression and cancer, which occurs upon exposure to mycotoxins by dermal, inhalation and mostly by ingestion (Peraica *et al.,* 1999; Pitt, 2000). Mycotoxicoses often remain unrecognised by medical professionals, except when large number of people in community is involved (Peraica *et al.,* 1999). Inhalation of fungal spores with less than 5 ppm aerodynamic diameter can enter the lungs, therefore, are able to cause severe types of mycotoxicoses, including toxic pneumonitis, hypersensitivity pneumonitis, tremors, chronic fatigue syndrome, kidney failure, and cancer (Sorenson, 1999).

Toxigenic micromycetes have been broadly classified into two groups according to their path of transmissions; (i) field fungi where fungi invade plant material in the field before harvest, during post-harvest handling and (ii) storage fungi during processing into food and feed products (Jouany, 2007). Fusarium genus *e.g. F. verticillioides* (formerly *F. moniliforme*), *F. roseus*, *F. tricinctum* and *F. nivale*, does not significantly contribute to the fungi storage or to the fungal contaminants found on damaged grains. However, there are ubiquitous soil organisms, which may infect grains directly in the field, thereby increasing mycotoxins levels during growth, ripening of grain and harvesting season (Jouany, 2007). Many Fusarium species can cause ear rot on maize and head scab or blight (FHB) when growing on wheat or other small grains in fields. Furthermore, fungi can grow on the non-grain part of plants, producing large amounts of mycelium towards the stem where it colonised the vascular bundles, which then inhibits the transport of nutrients at the upper part of the plant. The occurrence of draught in 1988 resulted in an increase corn-moulds contamination of all areas in the United States in 1989 while the same draught have raised the aflatoxins infection in corn and peanuts in parts of the South and Southeast US in 1990 (Wood, 1992).

Occurrence of mycotoxins in deteriorated palm oil and palm products namely palm kernel cake (PKC) have been reported in the past (Okoli *et al.,* 2007; Niefaizal *et al.,* 2017; Okogbenin *et al.,* 2014; Junsai *et al.,* 2021). PKC contains moderate amount of crude protein, ranges from 18% to 21%, 10% to 12% crude fibre, 4% to 7% fat, 3% to 6% ash and 64% carbohydrate (Rohaya *et al.,* 2020; Mohd Firdaus *et al.,* 2021).

Fungal growth that lead to mycotoxins incidence occurred frequently in palm kernel cake if preventive actions such as Good Manufacturing Practice (GMP) are neglected. The prevalent fungi that produce mycotoxins in PKC were Penicillium sp., Aspergillus sp., Fusarium sp., Mucor sp. and Rhizopus sp. (Niefaizal *et al.,* 2017; Okoli *et al.,* 2017; Pirouz *et al.,* 2017). A study conducted by Okogbenin *et al.* (2014) on the prevalent genera of fungi found in unsterilised palm oil were *Aspergillus niger*, Cochliobolus sp. and *Penicillium citrinum (Figure 2*).



Adapted from: Okogbenin *et al*., (2014).

Figure 2. Common fungi isolated from unsterilised palm oil. Aspergillus niger (a-i) and its spore close up under magnification of X40 (a-ii), Penicillium citrinum (b-i) and its spore close up under magnification of X40 (b-ii); and Cochliobolus sp.(c-i) and its spore close up (c-ii).

TYPICAL MYCOTOXINS IN PALM PRODUCTS

Aflatoxins

The prevalence exposure to mycotoxins, mainly aflatoxins on a human global scale have been reviewed by Williams *et al.* (2004). It was reported that ~4.5 billion people, living in developing countries are constantly exposed to largely uncontrolled amount of the toxin. Aflatoxins are produced primarily by two closely related fungi, *Aspergillus flavus* and *Aspergillus parasiticus* (Yin *et al.,* 2008). The conditions suitable for the growth of Aspergillus and production of aflatoxins in the field are 27°C to 38°C (optimum 30°C), water activity (AW) of 0.99 and high relative humidity of 85% (Fernández-Cruz *et al.,* 2010). There are four types of aflatoxins; namely Aflatoxin B_1 (AFB_1), Aflatoxin B_2 (AFB_2), Aflatoxin G_1 (AFG_1) and Aflatoxin G_2 (AFG_2) as shown in *Figure 1*. The toxins are generally found in fats containing food and feed such as ground nuts and their processed products, almonds, pistachios, Brazil nuts, maize, rice, figs, cotton seed and spices (Fernández-Cruz *et al.,* 2010).

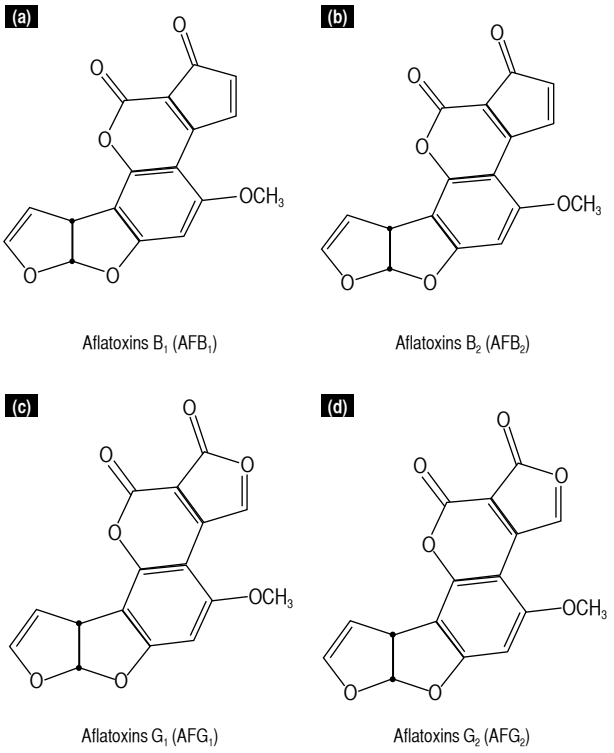


Figure 2. Chemical structure of Aflatoxin B_1(a), Aflatoxin B_2(b), Aflatoxin G_1(c) and Aflatoxin G_2 (d).

Aflatoxins received greater attention than any other mycotoxins due to their carcinogenic effects on susceptible animal and acute toxic effects in human (Wood, 1992). Chronic exposure to aflatoxins in farms and laboratory animals should compromised immunity, interference with protein metabolism and multiple micronutrients which negatively affect their health with factors accounted for more than 40% of the burden of disease in developing countries where short lifespan is prevalent (Williams *et al.,* 2004). The effect of aflatoxins has been demonstrated in swine where consumption of grains containing aflatoxins affected reproductivity indirectly through reduction in feed intake and growth, impaired liver and kidney function, delayed blood clotting, increased in susceptibility to bruising, and interfere with cellular humoral immune systems (Diekman and Green, 1992). Ruminants are comparatively resistant to aflatoxicosis, but the presence of aflatoxins in milk of dairy cows is closely monitored for human safety.

Ochratoxin A (OTA)

Ochratoxin A is a toxin produced by several species of *Penicillium* and *Aspergillus.* It is a probable carcinogen and may cause urinary tract cancer and necrosis of

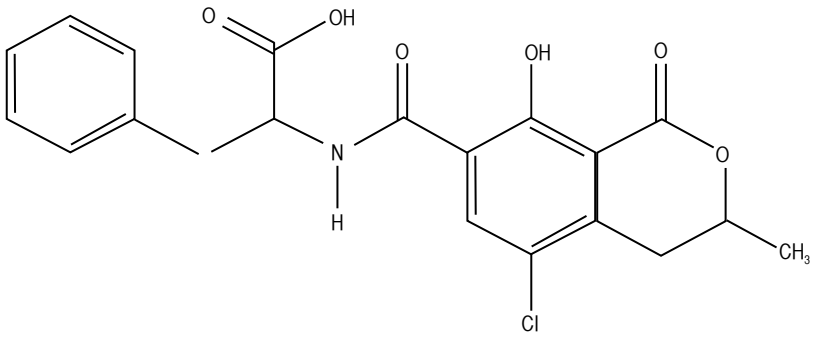


Figure 3. Chemical structure of Ochratoxin A.

kidney tissue in people from northern and eastern Europe (Pitt, 2000; Diekman and Green, 1992). The growth of *Aspergillus ochraceus* occurred over 8°C-37°C with the optimum temperature of 30°C on barley grains. The highest amount of OTA was obtained at 0.98 AW with 0.83–0.87 AW being the minimum AW for OTA production. OTA is common in cereals, beans and coffee, as well as in dried fruits and beverages such as beer, wine and grape juices (Fernández-Cruz *et al.,* 2010).

PREVENTION AND ANALYSIS OF MYCOTOXINS

Prevention of Mycotoxins

The high toxicity and carcinogenicity of mycotoxins caused a great monetary loss to the animal industry, which explains the major concern of food and feed industries is preventing them from entering the food chain (Diekman and Green, 1992; Jouany, 2007; Cigić and Prosen, 2009).

The first step in mycotoxins prevention should occur before any fungal invasion. Preventive actions in agricultural system are the most efficient before any fungal invasion occurred. Good farm management, culture methods to improve plant vigour, use of insecticides, fungicides and biological control, irrigation and avoiding postharvest contamination by controlling moisture, temperature and microbiological, insect and animal pests are fundamental fungal growth prevention methods (Fernández-Cruz *et al.,* 2010). However, the management of mycotoxins seemed to be impractical in developing-countries due to food systems and economics. Therefore, the strategy of using food additives such as mycotoxins binder may provide an effective and economical new approach to protect human population and farm animal from the toxins (Williams *et al.,* 2004).

The second step of mycotoxins prevention is during the period of fungal infestation of plant material and mycotoxin production. In this step, detoxification is applied towards the contaminated area. However, detoxification of mycotoxins by different physical, chemical and biological methods are less effective and occasionally restricted because of concerns on safety, possible losses in nutritional quality of the treated commodities and cost implications (Fernández-Cruz *et al.,* 2010).

Great success in controlling mycotoxins and microbial contamination has been achieved in palm oil through steam sterilisation. This is a technique used to prolong the shelf life of food by killing all the microorganisms. It generally involves heating the food products using steam at temperatures between 110°C-121°C for about 15 to 20 min while some canned products may be heated for up to 1 hr (Okogbenin *et al.,* 2014). Although steam sterilisation could clearly eliminated all microorganisms from the oil, however, it had adverse effect on the chemical qualities of the oil in which important phytonutrients such as carotene, were reduced and were slightly reduced the Deterioration of Bleachability Index (DOBI) values (Okogbenin *et al.,* 2014).

Analysis of Mycotoxins

Analysis of fungal toxins are difficult and require specific procedures due to their diverse chemistry and only trace amount in complex matrices of feedstuff and food (Chu, 1992; Richard *et al.,* 1993). Major error in analysis of these mycotoxins arise from inadequate sampling and inefficient extraction and cleanup procedures. In addition, the determinative step in the assay for each of these toxins is sensitive to levels below those that are considered

maximum permissible levels in human and animal (Richard *et al.,* 1993; Cigić and Prosen, 2009).

Rapid progress of mycotoxin analysis has been established during the last few years with the successful development of a simplified sample cleanup protocols and new chromatographic methods (Chu, 1992). More sensitive and versatile instruments such as high-resolution mass spectrometry (MS) and Liquid Chromatography–Tandem Mass Spectrometry (LC-MS/MS) are available to detect mycotoxins at lower level (Junsai *et al.,* 2021). Besides high-end machine to detect mycotoxins, an enzymatic assay to determine lipase activity is also a good precursor to detect *Aspergillus flavus* in deteriorated oil (Ibrahim *et al.,* 2017).

CONCLUSION

In conclusion, the occurrence of mycotoxin is unavoidable if strategic and systematic prevention plan is not taken carefully. GMP has to be adopted from plantation until production and storage of products. Although palm oil has not been affected by the mycotoxins due to steam sterilisation, repeated quality surveillance should be applied all the time.

REFERENCES

Chu, F S (1992). Recent progress on analytical techniques for mycotoxins in feedstuffs. *J. Anim. Sci., 70*: 3950-3963.

Cigić, I K and Prosen, H (2009). An overview of conventional and emerging analytical methods for the determination of mycotoxins. *Intern. J. Mol. Sci. 10*: 62-115.

Diekman, M A and Green, M L (1992). Mycotoxins and reproduction in domestic livestock. *J. Anim. Sci. 70*: 1615-1627.

Fernández-Cruz, M L; Mansilla, M L and Tadeo, J L (2010). Mycotoxins in fruits and their processed products: Analysis, occurrence and health implications. *Journal of Advanced Research, 1*: 113-122 .

Ibrahim, R; Ezihe, M and Magaji, H M (2017). Various levels of mycotoxins detected from different deteriorated vegetable oils (garlic oil, olive oil, and soya bean oils) sold in Bauchi metropolis of Bauchi State, Nigeria. *International Journal of Scientific & Engineering Research, 8*: 1436-1451.

Jouany, J (2007). Methods for preventing, decontaminating and minimizing the toxicity of mycotoxins in feeds. *Animal Feed Science and Technology, 137*: 342-362.

Junsai, T; Poapolathep, S; Sutjarit, S; Giorgi, M; Zhang, Z; Logrieco, A F; Li, P and Poapolathep, A (2021). Determination of multiple mycotoxins and their natural occurrence in edible vegetable oils using liquid chromatography-tandem mass spectrometry. *Foods, 10*: 1-12.

Mohd Firdaus, O; Rohaya, M H; Miskandar, M S and Astimar, A A (2021). Nutrient enhancement of palm kernel cake via solid state fermentation by locally isolated *Rhizopus oryzae* ME01. *J. Oil Palm Res., 34 (1)*: 92-103.

Niefaizal Abdul Hammid, A; Abdul Mutalib, S and Amri Ibrahim, N (2017). Natural occurance of fungi and aflatoxins of palm kernel cake in Malaysia: A preliminary study. *Intern. J. Adv. Res. and Inno. Ideas in Edu., 3(5)*: 554-558.

Okogbenin, O B; Okogbenin, E A; Odigie, E E and Ojieabu, A (2014). Isolation of food pathogens from freshly milled palm oil and the effect of sterilization on oil quality parameters food pathogens from freshly milled palm oil and the effect of sterilization on oil quality parameters. *J. Food Security, 2*: 65-71.

Okoli, I C; Ogbuewu, P I; Uchegbu, and M C; Opara, M N; Okorie, J O; Omede, A A; Okoli, G C & Ibekwe, V I (2007). Assessment of mycoflora of poultry feed raw materials. *J. American Science, 3(1)*: 5-9.

Peraica, M; Radic, Â B; Lucic, Â A and Pavlovic, Â M (1999). Toxic effects of mycotoxins in humans. *Bulletin of the World Health Organization, 77 (9):* 754-766.

Pirouz, A A; Selamat, J; Iqbal, S Z; Mirhosseini, H; Karjiban, R A and Bakar, F A (2017). The use of innovative and efficient nanocomposite (magnetic graphene oxide) for the reduction on of *Fusarium mycotoxins* in palm kernel cake. *Scientific Reports, 7*: 1-9.

Pitt, I J (2000). Toxigenic fungi and mycotoxins. *British Medical Bulletin, 56 (1)*: 184-192.

Rohaya, M H; Ridzuan, R; Che Rahmat, C M; Nu'man, A H; Mohd Firdaus, O and Astimar, A A (2020). Quality improvement of palm kernel cake as broiler feed using pre-cleaning system. *J. Oil Palm Res., 33 (3)*: 458-472.

Richard, J L; Bennett, G A; Ross, P F and Nelson, P E (1993). Analysis of naturally occurring mycotoxins in feedstuffs and food. *J. Anim. Sci., 71*: 2563-2574

Sorenson, W G (1999). Fungal spores: Hazardous to health? *Environmental Health Perspectives, 107(3)*: 469-472.

Williams, J H; Phillips, T D; Jolly, P E; Stiles, J K; Jolly, C M and Aggarwal, D (2004). Human aflatoxicosis in developing countries: A review of toxicology, exposure, potential health consequences, and interventions. *Am. J. Clin. Nutr. 80*: 1106-1122

Wood, G E (1992). Mycotoxins in foods and feeds in the United States. *J. Anim. Sci. 70*: 3941-3949

Yin, Y N; Yan, L Y; Jiang, J H and Ma, Z H (2008). Biological control of aflatoxin contamination of crops. *J. Zhejiang Uni. Science, 9*: 787-792