Mycotoxins in Mozambique: Need for a national monitoring programme

The occurrence of mycotoxins poses a threat to public health in Mozambique, with several cases of poisoning in humans caused by aflatoxins after consumption of groundnuts and maize reported before 1975. Over time, the control and monitoring of mycotoxins in agricultural and non-agricultural food and feed seem to have dropped significantly in Mozambique. So, the objective of this review is to recommend the implementation of monitoring and control of mycotoxins and fungal development. From our review, we note that data regarding mycotoxins in Mozambique are very limited and this makes it difficult to assess the spatial and temporal occurrence of mycotoxins in Mozambique. The scarcity of data does not mean that mycotoxins do not occur in Mozambique because the few studies that are available have confirmed the presence of mycotoxins in food and feed at concentrations above permissible limits in many countries of the world. This situation indicates a need for the creation of mycotoxin monitoring programmes involving the ministries of agriculture and public health (in coordination with universities) at the national level.

**Significance:**

This review provides relevant information that can help local authorities in Mozambique to implement a mycotoxin monitoring programme.

**Introduction**

Mozambique (Figure 1) is a sub-Saharan African country with 29.67 million inhabitants distributed in 11 provinces, according to the last population census carried out in 2017 (Figure 1). Around 80% of the population depends on agriculture as their source of income in Mozambique, and agriculture contributes 24% of the gross domestic product. Unfortunately, some of the most produced crops, such as maize, cassava, and peanuts, are easily contaminated by mycotoxins (secondary metabolites produced by filamentous fungi). These mycotoxins are mainly aflatoxins (AFs) at levels above the limits recommended by food organisations in many parts of the world. Mycotoxins constitute one of the greatest threats to public health worldwide, including in Mozambique where the mycotoxin risk is around 60–67%. The exposure to AFs, for example, is linked to several health problems, including malnutrition that could cause delayed growth of the foetus and child.

![Figure 1: Map of Mozambique. The areas in red indicate where mycotoxins have been detected and the green circles indicate the institutions for food and feed sampling and mycotoxin quantification in Mozambique: A – Agricultural Research Institute of Mozambique, B – National Laboratory for Water and Food, and C – Eduardo Mondlane University.](image-url)
the human food chain as well as animals that can later contaminate other food products such as milk, eggs, meat, and other related products. Cases of human poisoning caused by AFs after consumption of groundnuts and maize have been reported in Mozambique since pre-independence times. A survey related to mycotoxins carried out during 1968–1974 in Inhambane Province generated the first data regarding the presence of mycotoxins in Mozambique.\textsuperscript{8,9} The data from that survey showed a strong correlation between hepatocellular carcinoma prevalence and AFs found in groundnut and maize.\textsuperscript{8,9} The few studies that have been undertaken indicate the presence of AFs, fumonisins (FBs), ochratoxin A, patulin, and citrinin, among other mycotoxins, in maize and feed.\textsuperscript{8,10,11} These data suggest the need to reflect on the creation and implementation of mycotoxin monitoring programmes in Mozambique (Figure 1) in order to protect public health. The objective of this review was to recommend monitoring and control of mycotoxins in food and feed to the government of Mozambique as well as practical strategies to avoid possible fungal contamination and occurrence of mycotoxins in food and feed from field to store.

**Mycotoxins and regulation worldwide**

Mycotoxins are secondary metabolites produced by several fungi; the most reported species belong to Aspergillus, Penicillium, Fusarium and Alternaria genera. These species can occur and grow generally in agricultural food and beverages such as wine and beer.\textsuperscript{12} Species of Fusarium and Alternaria contaminate and produce mycotoxins during the growing season of the host crops (in the field). Aspergillus species may contaminate both field and stored crops, while hosts of Penicillium are mainly postharvest mycotoxin-producing fungi.\textsuperscript{12} However, the occurrence is also reported in animal-derived foods such as meat, eggs, and milk.\textsuperscript{16,15,19} Due to higher toxicity and occurrence (depending on the toxin), some mycotoxins have been legislated and monitored (Table 1) in many parts of the world since 1960.

According to the international inquiry conducted by the National Institute for Public Health and the Environment and Agricultural Services in Dutch Embassies around the world in 2002/2003, at least 99 countries (most countries with regulations in action) had specific regulations for mycotoxins for food and/or feed in place. The data received from the inquiry also indicated that all countries had at least regulatory limits for AFB1 or the sum of AFB1, AFB2, AFG1, and AFG2 in foods and/or feeds.\textsuperscript{20} The permitted limit of most reported mycotoxins varies according to each country and matrix (food, feed, and/or other); examples are shown in Table 1. According to legislation, any analytical technique (i.e. LC, ELISA, and others) with a limit of detection and quantification below the permitted limit of mycotoxins for each matrix is suitable to be used for mycotoxin monitoring. However, some factors affect the implementation of mycotoxin regulatory tools in many parts of the world, mainly in less developed countries such as some African countries. These factors include toxicological and exposure data to mycotoxins; knowledge of the distribution of mycotoxin concentrations within commodity or product lots; the availability of appropriate analytical methods; legislation in other countries with which trade contracts exist; the need for sufficient food supply; and the lack of trained staff for mycotoxin monitoring.

**Incidence of mycotoxins in Mozambique**

Data regarding mycotoxins in Mozambique date from 1960 after a survey was conducted in the Inhambane Province (1960–1974) that correlated the incidence of hepatocellular carcinoma and AFs contamination in the most consumed maize and groundnuts.\textsuperscript{3,4,14-16} Table 2 presents the occurrence of mycotoxins in Mozambique from 1960 to date. AFB1, AFB2, G1 and G2, produced by Aspergillus flavus, were detected in Nampula (1997–1998) in groundnuts collected from farmers at lifting and after drying/curing, and from traders. The predominant AF variants were B1 and G1 in samples from traders and at lifting, respectively. The content of all mycotoxins ranged from 83 μg/kg to 1126 μg/kg.\textsuperscript{16} Another AF survey on groundnuts (Arachis hypogaea L.) carried out in the Nampula and Cabo Delgado Provinces during December of 2015/2016 showed a content of total AFs ranging from 2 to 30 μg/kg and 5 to 35 μg/kg, respectively.\textsuperscript{46} Groundnuts are the main food source in Mozambique and Nampula. Cabo Delgado is considered the major producer of groundnuts in the northern region of Mozambique. In all these studies, the content of AFs was higher than recommended in many parts of the world where the maximum limit permitted is between 0.025 μg/kg and 20 μg/kg for the different matrices of food for human consumption (Table 1).

| Mycotoxins | Limit (μg/kg) | Food and beer | Feed |
|------------|--------------|---------------|------|
| Ochratoxin A | 0.5–10 (EU)\textsuperscript{22,23} | 2–20 (Brazil)\textsuperscript{23} | 2–10 (China)\textsuperscript{24} |
| AFB1 (SA)\textsuperscript{23} | 0.02–10 (Indonesia)\textsuperscript{23} | 0.5–20 (Japan)\textsuperscript{23} | 0.025–15 (Malaysia)\textsuperscript{23} |
| Patulin | 0.005–40 (EU)\textsuperscript{23} | 0.05–20 (Korea)\textsuperscript{23} | 0.025–15 (Malaysia)\textsuperscript{23} |
| Phomopsin A | 0.5–20 (Australia, EU)\textsuperscript{23} | 0.5–20 (Korea)\textsuperscript{23} | 0.05–20 (Korea)\textsuperscript{23} |
| Sterigmatocystin | 0.5–20 (Czech Republic, Slovenia)\textsuperscript{23} | 0.5–20 (Korea)\textsuperscript{23} | 0.05–20 (Korea)\textsuperscript{23} |
| Zearalenone | 0.2–20 (SA)\textsuperscript{23} | 0.2–200 (EU)\textsuperscript{23} | 0.2–200 (Japan)\textsuperscript{23} |
| Ergosterol | 0.5–10 (EU)\textsuperscript{23} | 0.5–10 (Japan)\textsuperscript{23} | 0.5–20 (Japan)\textsuperscript{23} |
| Fumonisins | 0.2–20 (USA)\textsuperscript{23} | 0.2–2000 (USA)\textsuperscript{23} | 0.2–2000 (USA)\textsuperscript{23} |
| Trichothecenes | 0.2–2000 (USA)\textsuperscript{23} | 0.2–2000 (USA)\textsuperscript{23} | 0.2–2000 (USA)\textsuperscript{23} |

A study was carried out with samples of maize, groundnuts, millet and soy used as food and feed collected in the province capital and rural villages of the Nampula Province in 2010. Samples were collected in May 2010 as a bulk of 500 g or 1000 g where a representative amount of 200 g was stored at ambient temperature and transported to Austria for mycotoxin analysis by LC-MS/MS. Samples were stored at 4 °C in the African countries and at 20 °C in Austria until analysis.\textsuperscript{47} Legislated and non-legislated mycotoxins were analysed in maize, groundnuts, feed, and other samples of grains of sorghum (Sorghum spp.), millet (Pennisetum glaucum), rice (Oryza spp.), sesame (Sesame indicum), and wheat (Triticum spp.), grain-based processed foods (infant food formula, mixed couscous, cornflakes, and cookies), soy (Glycine max), dried fruits, and waste product from feed production. The content of...
the different mycotoxins (AFs, FBs, ochratoxin A, trichothecenes, moniliformin, sterigmatocystin, 3-nitropropionic acid, cyclopiazonic acid, citrinin, enniatins, alternariol, alternariol methyl ether, altertoxin I) in food is given in Table 2. AFB1 was observed more frequently in maize (3.4–636 µg/kg) than in groundnuts (5.6–15.5 µg/kg).47 In feed samples, mycotoxins detected include AFB1, FB1, ochratoxin A, zearalenone, moniliformin, cyclopiazonic acid, citrinin, alternariol, alternariol methyl ether, altertoxin I, enniatin A1, beauvericin and sterigmatocystin. The concentrations of all mycotoxins in all samples were much higher than the permitted limits worldwide.47

AFs were also detected in non-agricultural food samples (chicken) during May and June of 2016.10 The samples of chicken (livers and gizzards) were collected from industrial and local poultry production sectors located in Maputo and showed AFB1 contents ranging from 0.57 to 3.80 µg/kg and 0.68 to 2.12 µg/kg in livers and gizzards, respectively.10

More recently, in October 2021, the Mozambican food authorities (the National Inspection of Economic Activities and the National Institute of Standards and Quality) removed from markets in Maputo, Inhambane, Nampula and Sofala Provinces, 200-ml packages of apple juice after the National Authority of Food Security and Economic Inspection of Angola announced that some packages were contaminated by mycotoxin patulin.48 Southern African countries including Mozambique consume fruit juice and other food types produced by the South African company that recalled the product (Pioneer Foods). The removal of the apple juices was based on the production and expiration dates and barcodes of 200-ml packages. According to Pioneer Foods, at least 1000 packages of apple juice contaminated by patulin were introduced into Mozambique, but up until November 2021, only 622 had been removed.48 No monitoring of patulin in the apple beverages was carried out in order to protect the health of the public.

Based on this review, data regarding mycotoxins in Mozambique are very limited, and this makes it difficult to assess the spatial and temporal occurrence of mycotoxins in Mozambique including in relation to public health threats. The lack of monitoring programmes or non-publication of relevant experimental studies on mycotoxins contribute to the lack of data. On the other hand, this scarcity of data indicates that Mozambique

| Location      | Date                  | Sample               | Method                                      | Positive samples | Mycotoxins Concentration (µg/kg) | Technique     | Reference |
|---------------|-----------------------|----------------------|---------------------------------------------|------------------|----------------------------------|---------------|-----------|
| Nampula 1997–1998 | Groundnuts            | –                    | 34 Purchased from farmers at the time of lifting | 33               | AFB1 54–1041, AFB2 8–142, AFG1 55–1126, AFG2 3–510 | ELISA (Mozambique) | 45        |
| Nampula 2015–2016 | Groundnuts (Arachis hypogaea L.) | –                    | 10 Purchased from traders                   | 10               | AFB1 20–22, AFB2 2–5, AFG1 2–4, AFG2 0–1 | ELISA (Mozambique) | 46        |
| Magude 1969 and 1974 | Main meal (a carbohydrate staple, a protein-rich food and a green vegetable) | –                    | Collection of main meal of the day from surrounding homesteads | 27               | AFB1 0.82 | TLC (South Africa) | 9         |
| Inhambane 1968–1974 | Beans                | –                    | 9                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Cassava flour         | –                    | 25                                           | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Corn                 | –                    | 28                                           | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Dry cassava          | –                    | 1                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Forage               | –                    | 8                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Corn flour           | –                    | 16                                           | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Wheat                | –                    | 3                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Sorghum              | –                    | 1                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Sesame               | –                    | 2                                            | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Groundnut            | –                    | 34                                           | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Rice                 | –                    | 35                                           | –                | –                                | –             | –         |
| Inhambane 1968–1974 | Maize                | –                    | 12                                           | –                | –                                | –             | –         |

Table 2 continues...
## Table 2

| Location | Date       | Sample          | Food | Feed | Mycotoxins | Concentration (µg/kg) | Technique | Reference |
|----------|------------|-----------------|------|------|------------|-----------------------|-----------|-----------|
| Nampula  | May 2010   | Maize bought    | –    | –    | AFB1       | 16.3–363              | LC-MS/MS  | 8         |
|          |            | from sellers    | 13   |      | AFB2       | 6.9–31.4              |           |           |
|          |            |                 |      |      | AFG1       | 19.7–256              |           |           |
|          |            |                 |      |      | AFG2       | 9.6–40.2              |           |           |
|          |            |                 |      |      | AFM1       | 5.6–6.0               |           |           |
|          |            |                 |      |      | FB1        | 159–7615              |           |           |
|          |            |                 |      |      | FB2        | 27.7–3061             |           |           |
|          |            |                 |      |      | FB3        | 26.7–777              |           |           |
|          |            |                 |      |      | DON        | 116–124               |           |           |
|          |            |                 |      |      | DON-glu    | 12.6–32.5             |           |           |
|          |            |                 |      |      | NIV        | 20.2–45.9             |           |           |
|          |            |                 |      |      | ZEA        | 10.9–18.1             |           |           |
|          |            |                 |      |      | MON        | 98–1305               |           |           |
|          |            |                 |      |      | 3NPA       | 205–3553              |           |           |
|          |            |                 |      |      | CPA        | 6066                  |           |           |
|          |            |                 |      |      | CIT        | 276–5074              |           |           |
|          |            |                 |      |      | ENA1       | 0.1–1.0               |           |           |
|          |            |                 |      |      | ENB1       | 0.1                   |           |           |
|          |            |                 |      |      | BEA        | 0.1–3.56              |           |           |
|          |            | Groundnuts      | –    | –    | AFB1       | 3.4–12.3              | LC-MS/MS  | 8         |
|          |            |                 | 3    |      | AFB2       | 19.5                  |           |           |
|          |            |                 |      |      | AFG1       | 30.3                  |           |           |
|          |            |                 |      |      | 2NPA       | 223–1346              |           |           |
|          |            |                 |      |      | CPA        | 763                   |           |           |
|          |            |                 |      |      | B1         | 0.3                   |           |           |
|          |            |                 |      |      | BEA        | 0.1–24.0              |           |           |
|          |            |                 |      |      | STC        | 9.7                   |           |           |
|          |            | Bad quality     | –    | –    | AFB1       | 24–297                | LC-MS/MS  | 8         |
|          |            | maize used as    | 10   |      | AFB2       | 21.7–29.8             |           |           |
|          |            | feed            |      |      | AFG1       | 24.4–236              |           |           |
|          |            |                 |      |      | AFG2       | 8.7–47.8              |           |           |
|          |            |                 |      |      | AFM1       | 4.44–9.4              |           |           |
|          |            |                 |      |      | FB1        | 810–26579             |           |           |
|          |            |                 |      |      | FB2        | 13.5–7088             |           |           |
|          |            |                 |      |      | FB3        | 94.3–2294             |           |           |
|          |            |                 |      |      | OTA        | 5.4–12.4              |           |           |
|          |            |                 |      |      | DON        | 99.1–697              |           |           |
|          |            |                 |      |      | DON-glu    | 17.6–84.0             |           |           |
|          |            |                 |      |      | NIV        | 42.7–52.7             |           |           |
|          |            |                 |      |      | ZEA        | 11.2–28.2             |           |           |
|          |            |                 |      |      | MON        | 61.0–1601             |           |           |
|          |            |                 |      |      | 3NPA       | 201–6931              |           |           |
|          |            |                 |      |      | CTN        | 306–25487             |           |           |
|          |            |                 |      |      | AOH        | 5.8                   |           |           |
|          |            |                 |      |      | AEM        | 12.6                  |           |           |
|          |            |                 |      |      | ENA        | 0.6–7.9               |           |           |
|          |            |                 |      |      | ENA1       | 3.4–43.9              |           |           |
|          |            |                 |      |      | ENB        | 2.2–114               |           |           |
|          |            |                 |      |      | ENB1       | 0.1–84.4              |           |           |
|          |            |                 |      |      | B2         | 0.9–9.1               |           |           |
|          |            |                 |      |      | BEA        | 3.3–418               |           |           |
|          |            |                 |      |      | STC        | 11                    |           |           |

Table 2 continues...
Mycotoxin control in agricultural food and feed

Mycotoxin control in food and feed is at risk of high exposure to mycotoxins because of the presence of AFs at concentrations above the permitted limits of many countries.

Mozambique has the capacity for mycotoxic analysis using commercially available ELISA kits, which can help in monitoring and control, although it is not enough. The Mozambican laboratory responsible for agricultural-related issues is Instituto de Investigação Agrária de Moçambique (Agricultural Research Institute of Mozambique) which can also be used as a national laboratory for mycotoxin monitoring. Mycotoxin control is a challenge worldwide as the occurrence of mycotoxins is influenced by climate change phenomena. Therefore sophisticated techniques are needed worldwide, including in Mozambique, where higher levels of hepatocellular carcinoma have already been registered.

**Considerations and recommendations**

**Mycotoxin control in food and feed**

Mycotoxin control in agricultural food and feed is crucial in Mozambique as agricultural activity is the livelihood of most of the population. In addition, the reduction of mycotoxin levels in food and feed in Mozambique will confer international trade advantages because many countries worldwide have regulated the maximum level of mycotoxins in different food and feed. Based on the experiences of other countries, including some African countries, some strategies could be applied in Mozambique in order to control mycotoxins in food and feed, including education and extension, mainly in the rural areas through seminars and workshops. This strategy is crucial because it can change the minds of people living in these rural areas (localities and districts) and bring awareness to the danger related to the presence of mycotoxins in food.

Another strategy for controlling mycotoxins is to teach the techniques of good agronomic practices such as early harvesting; rapid drying; of good agronomic practices such as early harvesting; rapid drying; storage of groundnut pods and kernels after harvest; smoking and chemical fumigation during storage; desiccants (calcium chloride or silica gel) to remove moisture, and temperature control during storage are also recommended agronomic practices to reduce mycotoxin production.55 For example, unshelled and shelled groundnuts may be stored for a year at 7.5% moisture, 10 °C, and a relative humidity of 65%.56 Moisture and temperature control must also be guaranteed during transportation and sales processes to prevent sources of moisture such as leaking roofs and condensation arising from inadequate ventilation.57 Smoking and chemical fumigation during storage may also be applied to control mycotoxins, especially AFs.68-71 The most common antifungal agents are 5% sodium ortho-phenylphenate solution for groundnuts under field conditions and cinnamon, clove oils, 0.5% methyl eugenol for groundnut pods and kernels;69-71 lactic acid bacteria;72-74 pyrimethanil (anilinopyrimidine), and fludioxonil (phenylpyrrole)66 in bags.

The use of plant-derived compounds (plant extracts and essential oils) is also reported to be applicable to control fungal spoilage and mycotoxin production in foods.44 Extracts of Chenopodium ambrosioides (Mexican tea), Peumus boldus (boldo), Anthemis nobilis L. (chamomile), Malva sylvestris L. (malva), Adenocalymma alliaceum (garlic creeper), Allium sp., (zimmu), Artemisia gmelinii (Gmelin’s wormwood), Citrus limon L. (lemon), Citrus paradisi L. (grapefruit), Citrus sp. (mandarin and orange), and Cuminum cyminum (cumin), among others, showed inhibitory action against species of Aspergillus, Botryodiplodia, Fusarium, Pythium, and Sclerotium, among other mycotoxin-producing species in laboratory conditions.52-71 The extracts of these plants can be used in rural areas of Mozambique as an alternative to chemical antifungal agents as their preparation does not need any advanced technology.

### Table 2 continued

| Location | Date | Sample | Mycotoxins | Concentration (µg/kg) | Technique | Reference |
|----------|------|--------|------------|----------------------|-----------|-----------|
| Nampula  | May 2010 | Additional matrices were tested to a lesser extent and are referred to as ‘others’: millet (Pennisetum glaucum), grain-based processed food: soy (Glycine max) and waste products from feed production | 7 Bought from sellers and millet harvested in 2009 | | LC-MS/MS | 8 |

AF, aflatoxin; FB, fumonisins; DON, deoxynivalenol; NIV, nivalenol; ZEA, zearalenone; MON, moniliformin; NPA, nitropropionic acid; CPA, cyclopiazonic acid; CTN, citrinin; ENA, enniatin A; ENB, enniatin B; BEA, beauvericin; STE/STC, sterigmatocystin; AOH, alternariol; AEM, alternariol methyl ether; ATX, altenuadin; ELISA, enzyme-linked immunosorbent assay; TLC, thin layer chromatography; LC-MS/MS, liquid chromatography with tandem mass spectrometry.
Mycotoxins in AF-contaminated food and feed can be destroyed through physical techniques such as cooking, roasting, frying, spray drying, baking, irradiation by UV light, bright sunlight, and gas-filled tungsten lamps; these techniques showed destruction of AFs of 40–85%, depending on exposure time. Chemical techniques such as ozonation, ammoniation, and treatment with sodium bisulfite, potassium bisulfite, and sodium chloride may also be used to destroy mycotoxins.

**Mycotoxin monitoring in food and feed**

A crucial practical action for monitoring of mycotoxins in Mozambique would be to create a National Programme of Mycotoxins Monitoring (NPMM) involving the governmental departments of agriculture and public health, as well as universities. In addition to the Agricultural Research Institute of Mozambique under the Ministry of Agriculture and Rural Development, there is the National Laboratory for Water and Food Hygiene under the Ministry of Health in Mozambique. Both laboratories are in the capital city Maputo and their central location easily allows exchange with other institutions of academic and scientific research such as universities. These institutions have the minimum molecular techniques such as ELISA and chromatographic techniques for screening of mycotoxins in food and feed including fungal species through cooperation with the Biotechnology Centre of Eduardo Mondlane University. In the first phase, it will be necessary to train the staff working in these institutions and this training can be given by the Faculty of Sciences of the Eduardo Mondlane University or other institutions with staff trained in fungal mycology. The Agricultural Research Institute of Mozambique would be responsible for food and feed (including homemade beverages) sampling collection in all provinces and districts of Mozambique in all phases, i.e. before or immediately post-harvesting and during drying and subsequent storage, as well as mycotoxin chemical analysis and identification of producing species. For better results in the NPMM, cooperation with the National Laboratory for Water and Food Hygiene, institutions of academic and scientific research, and fishery institutes might be needed because mycotoxins and their producing species also occur in drinking (fresh) and coastal water, meat, fish, and other non-agricultural food. The maximum limits for each of the groups of mycotoxins to be monitored in the NPMM are suggested in Table 3. These values can be adopted from countries that already have mycotoxin monitoring programmes, such as those in the EU, South Africa, USA, Japan, Korea, and Malaysia. The specific maximum limit for each food or feed matrix can be discussed in its own forum by the Government of Mozambique, based on the most consumed and accessible food and feed in Mozambique.

**Table 3:** Recommended maximum limits of mycotoxins in food and feed in Mozambique

| Mycotoxin | Limit (µg/kg) | Food and beverages | Feed |
|-----------|--------------|-------------------|------|
| Ochratoxin A | 0.2–10 | 50–200 | – |
| Patulin | 10–50 | – | – |
| Phomopsin A | 5 | – | – |
| Sterigmatocystin | 0.5–20 | – | – |
| Aflatoxins (AF) | 0.025–10 (AFB1 + AFB2) | 5–20 (AFB1) | – |
| Zearalenone | 20–200 | 100–1000 | – |
| Ergosterol | 450–9000 | 1 000 000 | – |
| Agaric acid | 100 000 | – | – |
| Fumonisins (FB) | 200–4000 (FB1 + FB2) | 500–50 000 FB1 | – |
| Trichothecene | 0.2–2000 deoxynivalenol | 50–4000 deoxynivalenol | – |
| | 15–1000 (T-2 + HT-2) | 250–2000 (T-2 + HT-2) | – |

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**Competing interests**

We have no competing interests to declare.

**Authors’ contributions**

All authors collaborated on the compilation, writing and discussion of this review paper.

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