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Mycotoxins as one of the foodborne risks most susceptible to climatic change

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Abstract

The impact of climate change on agriculture and food safety is certain.This may affect mycotoxin concentrations as fungi with higher temperature optima for growth and mycotoxin production will dominate in regions with currently cooler climates, or become less prevalent as the temperatures become too high in areas where the temperature is already hot. In Serbia, recent drought and then flooding confirmed that mycotoxins are one of the foodborne hazards most susceptible to climate change. This paper ams to discuss the weather influence on the mycotoxicology situation and to point out the possibility of prediction and prevention of such future problems.

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Keywords: climate change; food safety; mycotoxins

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1. Mycotoxins

Mycotoxins are secondary metabolites of different types of fungus, belonging primarily to *Aspergillus*, *Penicillium* and *Fusarium* genera. Under favourable environmental conditions, when temperature and moisture are

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suitable, fungi proliferate and may produce secondary metabolites. They have globally significant implications on human and animal health, economy and international trade[3]. Animal feed and human food can be adversely affected. Fungi are a normal part of the microflora of standing crops and stored feeds, but the production of mycotoxins depends upon the fungi present, agronomic practices, the composition of the commodity and the conditions of harvesting, handling and storage[2]. The amount of toxin produced will depend on physical factors (moisture, relative humidity, temperature and mechanical damage), chemical factors (carbon dioxide, oxygen, composition of substrate, pesticide and fungicides), and biological factors (plant variety, stress, insects, spore load).

The accumulation of mycotoxins both before and after harvest largely reflects climatic conditions. *Fusarium* toxins are produced in cereal grains during high moisture conditions around harvest[14], whereas pre-harvest aflatoxin contamination of crops is associated with high temperatures, insect damage and prolonged drought conditions. Moreover, because *Aspergillus* can tolerate lower water activity than *Fusarium*, it is more likely to contaminate commodities both pre- and post-harvest, whereas *Fusarium* is more likely to be found as a contaminant pre-harvest[2]. These examples demonstrate that although it may be convenient to describe fungi as either pre- or post-harvest organisms, the actual colonisation and proliferation of fungi is not clear cut but depends on the environmental and ecological circumstances and the resulting toxins will differ accordingly.

Stored grain is not static as well. It is in a dynamic state and may become infested with fungi and insects. These interrelationships are affected by climatic factors such as temperature and humidity, by geographical location, by the type of storage container and by grain handling and transport. Moisture depends mostly on water content at harvest, the amount of drying, aerating, and turning of the grain before or during storage as well as the respiration of insects and microorganisms in the stored grain. If grain is dry when placed in storage, moisture content can only rise due to leaks or condensation. Grain may go into storage at a uniform temperature, but over a period the grain mass will cool at a different rate in the centre than at the periphery. As a result of temperature differentials moisture migrates through the storage bin, resulting in condensation and the provision of ideal conditions for mould growth or the development of ‘hot spots’ in localized areas. Microbial and insect growth in stored grain also results in moisture condensation and the potential development of ‘hot spots’. The minimum critical levels for the growth of fungi are 70–150 g/kg moisture (depending on commodity) and 80–85% relative humidity. Temperatures at which toxin production can take place vary from 0°C to 35°C, depending on fungal species. Most mycotoxins are very stable chemically and once formed, they will continue to contaminate that commodity and feeds manufactured from it[3]. Two most important factors which affect the life cycle of all microorganisms including mycotoxigenic moulds are water availability and temperature[9].

2. Climate change and mycotoxins

IPCC[6] states that more climate changes are ahead which will affect mycotoxins in food. Concentrations of methane, carbon dioxide, nitrous oxide and chlorofluorocarbons in the atmosphere are increasing, resulting in environmental warming, greater precipitation, or drought. Climate changes or extreme climatic events are already part of our everyday life and can be seen more and more frequently. Changing temperature and rainfall may threaten food security[7,11,12,19] and will have a negative impact especially in developing countries.

The EU green paper on climate change suggests that effects in Europe will be regional and either detrimental or advantageous, depending on region. This could increase the risk of migration of pathogens which might occur as a result of shifts in response to warmer, drought-like climatic conditions. Effects on plant physiology, including stomatal patterns on leaf surfaces, will influence transpiration and photosynthetic capacity and affect invasion by pests and pathogens. There is evidence that increased CO_2 and temperature may modify the phyllosphere mycoflora of cereals during ripening. This may have an effect on the colonization by mycotoxigenic fungal genera which contaminate food and raw materials[10].

Climatic changes resulted in specific extreme conditions in Serbia in 2011/12 and 2013/14 production years. According to the report of the Republic Hydrometeorological Service of Serbia[17], production year 2012 was characterized by pronounced climatic changes. Prolonged periods of extremely high air temperatures during June, July and August 2012, as well as precipitation deficit, resulted in severe and extreme droughts in many regions of Serbia. The hottest and driest period in the major part of the territory coincided with the most important generation phases of spring crops, thus causing substantial damage and losses in agricultural crop production manifested by high concentration of aflatoxins in maize and consequently in milk[7]. In 2014, in accordance with the new climate conditions and an environment with lot of rain and moisture[18] a large percentage of maize and wheat tested contained a new group, the *Fusarium* mycotoxins: zearalenone and deoxynivalenol[12].

3. European predictions

A high priority over the next decade is the collation of accurate contamination and weather data, together with the development of models to forecast the effects of climate change on mycotoxins, with a view to providing the necessary foresight for strategic adaptation to climate change[11,15,16]. Modeling studies provide increasingly realistic scenarios for the influence of changes in the magnitude and variability of precipitation, temperature, etc. on mycotoxin contamination.

High temperature and drought will reduce water availability and crop productivity in the south. Warming in the order of 3°C will result in a poleward dispersal of many plant species, or even entire communities, and changes in species assemblages. There may be increased aflatoxin and ochratoxin A from *Aspergillus spp*. and fumonisins in sub-Mediterranean countries (e.g. North Portugal) as the temperature increases. Aflatoxins in Northern Italy[4] and Serbia[13] have already been reported, as has the isolation of *A. Flavus* from Hungary[20].

Southern Europe will probably experience decreases of spring-sown crops (e.g. maize, sunflowers, and soybean) with them becoming more suitable for cultivation in Northern areas. Maize production is expected to increase by 30–50% in Northern European regions but to decrease strongly in the south of Europe. The mycotoxin problem may “follow the crop”. In Southern and South-Eastern Europe, an increase in the order of 4–5°C is projected and water availability will be reduced, particularly in summer. This effect combined could induce decreased agricultural yields (in the range of 10–30% in many regions), drought, heat waves, soil and ecosystem degradation and desertification. Drought and heat may increase aflatoxin levels generally[5].

Western and Atlantic Europe countries will experience an increase of ca. 2.5–3.5°C (2–3°C for UK and Irish Republic) with dryer and hotter summers. Due to higher volumes and intensities of precipitation, strong storms and floods are projected to be more frequent particularly in winter. Proper drying down of crops may be impaired causing increased mycotoxins in stored products.

For areas of central Europe, an increase of 3–4°C (4–4.5°C for Central Europe and Black Sea Regions) is projected and precipitation may increase in winter and decrease in summer, with an increased risk of floods. Agriculture is expected to be affected by soil erosion, loss of soil organic matter, migration of pests and diseases, summer drought and high temperature[5].

In northern Europe and Baltic States, temperature increase in the order of 3–4.5°C and an increase of yearly precipitation up to 40% are projected with risks for floods. The overall results of climate change would be an increase in crop yield (10–30% for warming in the range 1–3°C) and novel crops may be cultivated.

At higher temperatures, more insect pests will occur[6], by which mycotoxigenic fungi are spread[1,19]. More insects may increase insect-feeding birds perhaps resulting in more bird damage to crops, which will tend to increase the total amount of mycotoxins.

4. Mycotoxin prevention

There are a number of approaches that can be taken to minimize mycotoxin contamination in the food chain. Agricultural practices are recommended to control plant contamination. One of the strategies for the control of toxin production is linked to the possibility of limiting the infection by using varieties that have proved to be more resistant to fungi and insect injuries.

Chemical control of the pathogens is difficult because, to be efficient, the fungicides must be totally lethal, but if not, they stimulate mycotoxin production *in vitro*. Biological control with microbial antagonists or competitors can be integrated in contamination control strategies by spraying agents on plants at flowering stage to eradicate or limit the growth of toxin producers[8].

There are different possibilities for the post-harvest decontamination strategies. Damaged grains should be eliminated and the humidity level of the kernels must be lowered in order to reduce the possibilities of infection and the production of toxins by fungi. The temperature of storage has an effect on fungal growth and combined cooling and drying operations associated with ventilation systems are necessary to avoid the worsening of contamination during storage[8]. Farm feed storage and on-farm feeding systems can also contribute to mycotoxin exposure of the animals being fed. One important method for mycotoxin control is to alleviate and/or prevent harmful effects of mycotoxins already present in feed. There is the possibility of using various feed additives which either adsorb mycotoxins on their surface or they provide enzyme degradation of mycotoxins.

Generally, a “field to table” combating program against mycotoxins is needed. It should involve Good Agricultural Practice, Good Manufacturing Practice, Good Storage Practice, applying HACCP principles and Good Laboratory Practice for mycotoxin detection, as well as development of models to forecast the effects of weather conditions on mycotoxins for strategic adaptation to climate change.

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