Austin Journal of Microbiology

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Austin Publishing Group

Review Article

Continental Climate Changes on the Occurrence of Aflatoxin Producing *Aspergillus species*: Review

Kanyi KJ*
Faculty of Science and Informatics, University of Szeged, Hungary

***Corresponding author:** Kihika Joseph Kanyi, Faculty of Science and Informatics, University of Szeged, 6728 Othalmi Diaklakasok Szeged, Hungary

Received: May 03, 2018; **Accepted:** July 18, 2018; **Published:** July 25, 2018

Abstract

Most countries that occur in the middle latitudes (40˚ to 55˚ North) experience continental climates that are described to have large annual temperature differences, mostly with warm to very hot (and often humid) summers and sometimes cold or severely cold winters. The emission of Green House Gases that mainly include the CO_2 as a result of increased human activities has contributed to global warming with high temperatures being recorded in continental regions in Europe. As the climate changes, increased aflatoxin contamination of plants and farm produce in parts of Europe has been recorded from the main aflatoxin producing fungi belonging to the aspergilli genus that include: *Aspergillus flavus* and *A .parasiticus* respectively. *A flavus* has been recorded to occur in large amounts where temperatures are about 28˚C optimum for their growth and 28˚C - 30˚C for aflatoxin production. The consumption of aflatoxins has many detrimental effects to plants, animals and human life where humans suffer from increased nutritional deficiencies, immune suppression and hepatocellular carcinoma.

Aflatoxin B_1 is the most potent and it's abundantly produced by the fungal toxigenic strains. To control the spread of these mycotoxin fungal strains due to the climate changes in the continental zones, proper mitigation purposes to curb the harsh climatic conditions has to be effectively implemented and adhered to ensure that safe agriculture is practiced to produce mycotoxin free farm produce required to feed the increasing human population globally.

Keywords: Continental climate; Climate changes; Aflatoxin; Aspergilli; Toxigenic; Mitigation

Abbreviations

IPCC: Intergovernmental Panel on Climate Change; **CO_2:** Carbon Di Oxide; **EFSA:** European Food Safety Authority; **˚C:** Degrees Celsius; **TLC:** Thin Layer Chromatography; **HPLC:** High Performance Layer Chromatography; **GC:** Gas Chromatography; **ELISA:** Enzyme-linked Immunosorbent Assay; **EU:** European Union; **GHG:** Green House Gas

Introduction

Continental climates refers to the climates that are often described to have a significant annual variation in temperature characterized by the hot summers and cold winters. These climates tend to occur in the middle latitudes (40˚ to 55˚ North), where the prevailing winds blow overland, and these regions lack water bodies like the oceans and seas that can moderate the temperatures. Continental climates occur mostly in the Northern Hemisphere, where there are large land masses required for this type of climate to develop. Most of northern and northeastern China, eastern and south-eastern Europe, central and south-eastern Canada, and the central and upper eastern united States have this type of climate. In Continental climates, they experience continuous precipitation in the warmer months and it tends to be moderate in amount. A portion of the annual precipitation falls as snow during cold winters, and snow often remains on the ground for more than a month. Furthermore, the summer seasons experience thunderstorms and frequent cool temperatures but in these climates the summer weather is observed to be more stable than winter weather. However, according to [1], it has been found out that conditions adverse to the growth of many plants like (drought stress, temperature stress, stress induced by pest attack, poor nutrient status, etc.) encourages the fungal partner to develop more than under conditions that are favorable to the plant with the expectation of greater production of mycotoxins.

Changes in Continental Climates

Continental climates are experiencing changes and there is now unequivocal evidence that climate change is taking place, and it is very likely, that increases in atmospheric greenhouse gas concentrations resulting from the increased human activities mainly through atmospheric pollution are causing global warming. In Europe the effects of climate changes are already being observed and further changes in climate are projected to take place in the future. During the 20th century, there was an increase in average annual surface temperature experienced in Europe of about 0.8˚C, which was accompanied with an increased rate of warming over time. It was found out that the 1990s were the warmest on record [2]. The warming experienced has been stronger in most of the continental climatic regions in winter than in summer. An increase in warm extremes has been observed rather than a decrease in cold extremes [3].

Citation: Kanyi KJ. Continental Climate Changes on the Occurrence of Aflatoxin Producing *Aspergillus species*: Review. Austin J Microbiol. 2018; 4(1): 1021.

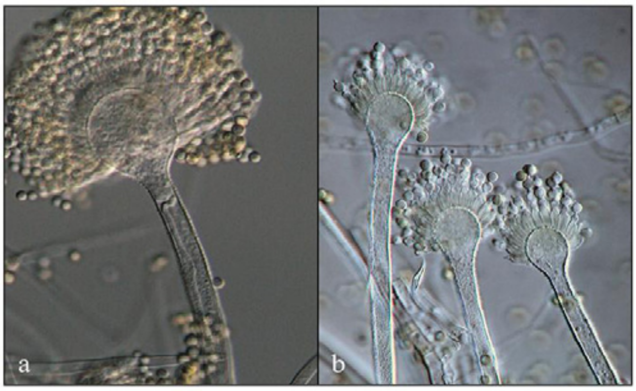

Figure 1: (a) Bi-seriate and (b) mono-seriate heads of *A. flavus*.

The IPCC [4] (Eds) reports that the world's land ecosystems act as a major sink in the contemporary global carbon cycle and, therefore it alleviates the rise of atmospheric CO_2 concentrations from global CO_2 emissions and as a consequence there is an overall effect on climate change.

Europe will also be increasingly confronted with the impact of climate change. Climate change will come about gradually as a result of increases in average temperatures and changes in precipitation levels. However, in the shorter term extreme weather changes will be felt which will constitute a major short-term challenge but the main impact of these changes will be felt in the long term partly because of the presence of multiple complex factors that influence the carbon balance of terrestrial ecosystems including climate change, land-use and land-cover change (forest regrowth, fire suppression etc.) and nitrogen deposition, and CO_2 increase in the atmosphere [5].

In their report, European Food Safety Authority (EFSA, 2007), evidenced the emerging issue of potential aflatoxin contamination of several plants that include corn, almonds and pistachios that were grown in areas of Southern Europe, due to the changes in the subtropical climate occurring in some recent years.

The quantity of aflatoxin producing fungi that is associated with crops and soils varies with different climates. These fungi compete poorly under cool conditions and the quantity of *Aspergillus flavus* in cool areas (temperature minima below 20˚C) is usually low compared to warmer regions (temperature minima N25˚C) where aflatoxin-producers are always commonly found throughout soils, air, and on crop surfaces [6,7]. The crops that are grown in warm climates have greater likelihood of infection by aflatoxin producers and in some regions, infection only occurs when temperatures increase in association with drought conditions [8,9].

Aspergillus flavus as an Aflatoxin Producer

The *Aspergillus* genus is well known for its ability to secrete a variety of secondary biologically active chemical compounds that include antibiotics, mycotoxins, immune-suppressants, and cholesterol lowering agents [10,11]. Aflatoxins are the most thoroughly studied mycotoxins produced predominantly by the main causative agent *Aspergillus flavus* (Figure 1). According to Maren [12], *A. flavus* has a broad host range as an opportunistic and a very common pathogen of soil, plants, animals and insects and it causes storage rots in numerous crops and it produces the highly regulated mycotoxin, aflatoxin B_1.

The major concern with this fungus in agriculture is that it produces highly carcinogenic toxins called aflatoxins which are a health hazard to animals. The *Aspergillus* genus is widely known to produce various fungal secondary metabolites and the aflatoxins are toxic metabolites produced by different species of toxigenic fungi, called mycotoxins.

Humans are prone to be exposed to aflatoxins due to the periodic consumption of contaminated food, contributing to an increase in nutritional deficiencies, immune-suppression and hepatocellular carcinoma [13].

Aspergillus flavus is classified under the section *Flavi*. This section is well studied and known to contain the major economically important aflatoxin-producing fungi that include the *A. flavus* and *A. parasiticus*. The other less common aflatoxin-producing species in this section are *A. nomius*, *A. pseudotamarii*, *A. bombysis* and *A. parvisclerotigenus*. Four species not in section *Flavi* are known to produce aflatoxin: *A. ochraceoroseus*, *A. rambellii*, Emericella *venezuelensis* and *E. astellata* [14].

Aflatoxins as a Secondary Fungal Metabolite

Aflatoxins were first identified from peanut samples in 1961 when it was discovered that more than 100,000 turkeys died from acute liver necrosis referred to as the Turkey-X disease as a result of the toxicity of animal feeds containing contaminated peanut meal [15,16].

There are two general forms of the disease that is caused as a result of exposure to aflatoxin, aflatoxicosis. Acute aflatoxicosis results in death while chronic aflatoxicosis causes cancer with the liver as the primary target organ, immune suppression, teratogenicity and other symptoms [17]. Aflatoxins produced by *Aspergillus flavus*, *A. parasiticus*, *A. nomius* and *A. wentii*, are genotoxic carcinogens, they are also potent acute toxins and widely distributed mainly associated especially with the maize, groundnuts, tree nuts, figs, dates and certain oil seeds such as cotton seeds.

Aflatoxins are a group of structurally related difuranocoumarins that were named as aflatoxins B_1, B_2, G_1, and G_2 (Figure 2) based on their fluorescence under UV light (blue or green) and the numbers indicating their relative migration distance on a thin-layer chromatographic plate.

Aflatoxin B_1 (Figure 2) is the most potent natural carcinogen known [18] and is usually the major aflatoxin produced by toxigenic strains. Apart from the major aflatoxins named above, over a dozen of other structural analogues including aflatoxins P_1, Q_1, B_2a, and G_2a have been described [19] (Ed), especially as mammalian biotransformation products of the major metabolites, while aflatoxin D_1 was detected in ammoniated corn and aflatoxin B_3 as a metabolite of *A. flavus* [20]. Aflatoxin M_1, a hydroxylases metabolite, is found primarily in animal tissues and fluids (milk and urine) as a metabolic product of aflatoxin B_1 [21].

Thin Layer Chromatography (TLC) technique became the standard for analysis as well as screening of aflatoxins, and is still

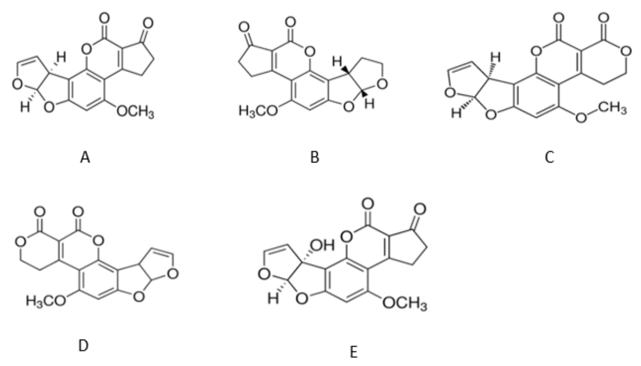

Figure 2: Chemical Structures of major aflatoxins. (A) Aflatoxin B_1, (B) Aflatoxin B_2, (C) Aflatoxin G_1, (D) Aflatoxin G_2, (E) Aflatoxin M_1.

used because it is simple to use and inexpensive. Other methods including High-Performance Liquid Chromatography (HPLC), Gas Chromatography (GC) and immunological methods such as Enzyme-Linked Immunosorbent Assay (ELISA) are also used [22,23].

The most extensive legislation on limits for mycotoxin contamination of raw commodities and derived products exists in the EU and it has been put in place to protect people from consuming mycotoxins contaminated farm produce *Aspergillus flavus* total aflatoxins are potent to humans and are carcinogenic, affecting the liver while adverse effects of *A. parasiticus* Aflatoxin B_1 are observed in various animals, especially chickens and *A. nomius* aflatoxin $M_1$is present in (milk) [24].

These mycotoxins can have a significant effect on human and animal health because they can be carcinogenic (e.g. aflatoxins) and they have been found to be very heat-stable and thus difficult to destroy during processing. This has resulted in strict legislative limits in many parts of the world for mycotoxins in a wide range of foodstuffs and other consumer products [25] as compared to the developing countries where they are not as extensive, especially for internal consumption of staple food products [26].

According to the IPCC (2007) report, the presence of mycotoxins in food will be affected by the Climate Change (CC) that favors the growth of the fungi producing these mycotoxins. In 2003-4 there were very hot and dry episodes in parts of northern Italy where maize is a key animal feed for cattle that in turn provide the milk for the important cheese production regions. However, because of the very dry conditions in those years, *Aspergillus flavus* became a significant problem. *A. flavus* generally has a wide range of temperature tolerance (19˚C-35˚C) with about 28˚C optimum for growth and 28˚C-30˚C for aflatoxin production [27].

Mitigation Plans for the Current Climate Changes

The European Union has responded to the challenge of the observed continental climate changes by setting ambitious mitigation goals for itself. The EU's objective has been to limit global average temperature increase to 2˚C compared to the pre-industrial levels.

Green House Gases emissions still remains to be a major challenge that is contributing to the continental climate changes and the European Council Presidency Conclusions endorsed a decision for the EU to unilaterally reduce Green House Gases (GHG) emissions by 20% by the year 2020 as compared to 1990, and agreed to increase emission reductions to 30% if other developed countries take up the initiative of reducing these gases. To achieve these targets, the most developed countries with comparable reduction ambitions have to support the developing countries in mitigating the problem of climate change. For the developed countries to achieve medium to long term emission reductions, they have to collectively reduce their emissions by 60-80% by year 2050. According to the EU Emissions trading scheme, which has been in place since the beginning of 2005, is aimed at reducing the emission of GHG into the atmosphere from large energy-intensive installations and it will assist in reducing the high rising global temperatures especially in the continental regions.

Conclusion

The continental zone is experiencing high rise in temperatures and it has been attributed to the increased human activities that are resulting to atmospheric pollution and the emission of GHG that contribute to higher average environmental temperatures that mainly favors the growth of mycotoxin producing fungi that could contaminate the farm produce with the toxic aflatoxins that are very detrimental to plants, animal and human life.

Countries within the continental regions that are experiencing climatic changes with very hot summers and cold winter up have to follow the mitigation plans set by the European Union that will in the long run play a role in curbing the extreme climatic changes in the continental zones for safer Agriculture that will be free from mycotoxigenic fungi.

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Austin J Microbiol - Volume 4 Issue 1 - 2018
ISSN: 2471-0296 | www.austinpublishinggroup.com

Citation: Kanyi KJ. Continental Climate Changes on the Occurrence of Aflatoxin Producing *Aspergillus species*: Review. Austin J Microbiol. 2018; 4(1): 1021.