Global warming, climate change and the safety of food of animal origin

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Abstract

Climate change has already been seen to have had an impact on the safety of food of plant and animal origin in Europe. Intensive monitoring has recently been performed on the effects of climate change and global warming on the occurrence and distribution of toxigenic microfungi (moulds), producers of aflatoxins (e.g. *Aspergillus flavus*), ochratoxin A (e.g. *Aspergillus carbonarius* and *Penicillium verrucosum*) and *Fusarium* mycotoxins (e.g. *Fusarium graminearum* and *F. verticillioides*) in maize in temperate climates. The contamination of cereal grain with ochratoxin A has resulted in the subsequent entry of ochratoxin A into pork meat and pork kidneys via the pork feed chain. The contamination of maize grain with aflatoxin B_1 has resulted in the subsequent entry of aflatoxin M_1 into milk via the dairy cow feed chain. The occurrence of ticks contaminated with the tick-borne encephalitis virus at over 1 000 metres above sea level is other example. The tick-borne encephalitis virus can be transmitted during consumption of raw (non-pasteurised) milk and milk products from infected animals, primarily goats. Tick-borne encephalitis may be caused after consumption of contaminated raw milk and milk products if the infected person has not been vaccinated.

Climate change, food of animal origin, food safety, mycotoxins, tick-borne encephalitis, toxigenic moulds

Introduction

Global climate change is a widely recognised fact, evidence of which comes from the evaluation reports from the Intergovernmental Panel on Climate Change (IPCC). The IPCC is an intergovernmental scientific organisation established in 1988 by the UN – World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to evaluate the risks of climate change. The mission of the IPCC is to provide a comprehensive scientific assessment of current scientific, technical and socio-economic information from all around the world on the risks of climate change caused by human activity, their potential environmental and socio-economic consequences and the possibilities of adaptation to these consequences or alleviating their effects.

The IPCC is an internationally recognised authority in climate change and draws up reports issued at regular six-year intervals that represent agreement among leading climatologists and a consensus among the participating governments (IPCC 2016).

Climate change is characterised by a clear and continuing growth in the average temperature of the Earth's climatic system. The warming of the seas and oceans, warming of the atmosphere, the thawing of icebergs and rising sea and ocean levels are the observed manifestations of global climate change. The causes of climate change include increased concentrations of the greenhouse gases CO_2, CH_4 and N_2O resulting from human activity, primarily the burning of fossil fuels and changes to landscape use such as deforestation, and increased solar activity (Oreskes 2004; Riahi et al. 2011; IPCC 2016). As a result of climate change in Europe, recent decades have seen an increase in the average temperature of 0.45 °C and a change in the landscape water balance, while there will continue to be more frequent extreme weather events in the future (heatwaves, droughts, flooding and

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gales) (IPCC 2016). The World Health Organisation (WHO) states in its materials that tens of thousands of people all over the world die every year of disease, injury and heat associated with climate change. Another consequence of climate change in Europe are serious changes in the geographical distribution of illnesses transmitted by mosquitoes (e.g. malaria) and ticks (e.g. borreliosis) (Caminade et al. 2014; Hales et al. 2014; WHO 2016). Climate change in Europe is resulting in the spreading of microscopic toxigenic filamentous fungi (moulds) into the temperate climatic zone. These significant toxigenic moulds include *Aspergillus flavus* (producing aflatoxins B_1 and B_2) and *A. carbonarius* (producing ochratoxin A) (Medina et al. 2015). A change will also been seen in the ecology of toxigenic moulds and the colonisation of crop plants by toxigenic moulds producing *Fusarium* and *Alternaria* mycotoxins (Paterson and Lima 2011; Botana and Sainz 2015).

What anticipated consequences of climate change are likely to occur in relation to food safety? The following case studies have been selected in answer to this question for the purposes of this paper.

Climate change, toxigenic moulds and mycotoxins

As has already been said, a change in the ecology of the toxigenic moulds *Aspergillus flavus* (producing aflatoxins B_1 and B_2), *Aspergillus carbonarius* and *Penicillium verrucosum* (producing ochratoxin A) and *Fusarium* spp. (producing *Fusarium* mycotoxins) in the colonisation of crop plants is occurring in Europe as a result of climate change (Medina et al. 2015; Botana and Sainz 2015). A conference entitled "Climate Change and Mycotoxins in Food and Feed – A Challenge to the Safety and Assurance of High-quality Food and Feed" was held on 5th June 2015 at "EXPO Milano 2015". It was stated that climate change and extreme weather in Europe had a significant effect on the occurrence of high concentrations of aflatoxins in maize from the 2012 harvest and *Fusarium* mycotoxins in the 2013 and 2014 harvests (EXPO 2015).

Climate change and increased occurrence of *Fusarium* mycotoxins in maize

Climate change had a great influence on the occurrence of *Fusarium* mycotoxins (deoxynivalenol, zearalenone and fumonisins) in agricultural crops, and in maize in particular, in Europe, including the Czech Republic, in 2014. The Euromaiziers Association, which affiliates food maize processors, addressed a letter to the Committee for Agricultural Contaminants at the European Commission (DG SANTE) and the European Commission in which it states that food maize from the 2014 harvest contains high concentrations of *Fusarium* mycotoxins in spite of observation of the principles of proper agricultural practice. The Euromaiziers Association stated that the situation in 2014 was even worse than that in 2013 when intensive discussions on this issue began. Maize producers and processors are not able to observe the maximal limits for *Fusarium* mycotoxins in food maize stipulated in Commission Regulation (EC) No. 1881/2006. The Euromaiziers Association asked the European Commission to increase the maximal limits for *Fusarium* mycotoxins in food maize from the 2014 harvest. The situation regarding food maize, including a proposal for further action, was discussed at a meeting of the Standing Committee on Plants, Animals, Food and Feed. This exemption was not passed by a qualified majority during voting by EU member states.

The unfavourable situation regarding the contamination of food maize with *Fusarium* mycotoxins is confirmed unambiguously by the data from the Czech Republic. Those data provided by the Research Institute for Fodder Crops in Troubsko indicate that the average content of deoxynivalenol in grain from monitored samples of maize from the 2014 harvest was 10.7 $mg \cdot kg^{-1}$, with a maximal concentration of 28.3 $mg \cdot kg^{-1}$. The situation was also unfavourable for zearalenone, with almost half of the samples analysed showing a concentration greater than 350 μg·kg^{-1}, which is the maximal limit for unprocessed food maize. Data provided by the Central Institute for Supervising and Testing in Agriculture did not demonstrate such a high level of contamination (an average of 773.6 μg·kg^{-1} for deoxynivalenol, with a maximal value of 1 870 μg·kg^{-1}), though it can, nevertheless, be stated that the level of contamination of food maize was higher than is usual in the Czech Republic. Experts on expert fora in this country and around the world are discussing the effect climate change is likely to have on the increasing occurrence of *Fusarium* mycotoxins in cereals and on the health and yield of livestock animals (e.g. pigs and chickens) and the possible occurrence of residues of *Fusarium* mycotoxins in the meat and offal of livestock animals (Antonissen et al. 2014; EFSA 2014; Marroquín-Cardona et al. 2014).

Climate change and the occurrence of ochratoxin A in pork meat and pork kidneys

The topic of the effect of climate change, high temperatures and drought on the occurrence of ochratoxin A (OTA) in animal feed and the subsequent possibility of increased occurrence in pork meat and offal (kidneys) has been raised in recent years during expert discussions at the Mycotoxin Workshops of the Society for Mycotoxin Research. The results obtained to date by the project "ochratoxin A – Health Risk Assessment for Selected Population Groups in the Czech Republic" have not, as yet, confirmed these predictions (Ostrý et al. 2015). Only a few of the pork meat (8%) and pork kidney (8%) samples analysed in our study have been contaminated with OTA (pork meat – mean value 0.11 ng·g^{-1}, maximal value 0.2 ng·g^{-1}; pork kidney – mean value 0.13 ng·g^{-1}, maximal value 0.46 ng·g^{-1}) (Ostrý et al. 2015).

In Serbia, for comparison, 26.6% of pig livers contained OTA in a range of 0.22 – 14.5 ng·g^{-1} (Milicevic et al. 2012). The data on the occurrence of OTA in pork kidneys was very similar (33.3%), with a maximal concentration of 52.5 ng·g^{-1}. In Portugal, 25% of pork meat samples were contaminated within a range of 0.06 – 0.405 ng·g^{-1}, with a maximum of 0.578 ng·g^{-1} (Duarte et al. 2013). In the Canadian Total Diet Study in years 2008 – 2009, OTA was found only in samples of fresh pork meat (OTA concentrations of 0.03 and 0.23 ng·g^{-1}) and cured pork meat (OTA concentrations of 0.06 and 0.20 ng·g^{-1}) (Tam et al. 2011).

Follow-up monitoring of OTA determination in pork kidney is extremely important for the prediction of the values of pork meat contamination in the future.

Climate change and increased occurrence of aflatoxin M_1 in cow's milk

Climate change had a large effect on the occurrence of aflatoxin B_1 in maize in southern Europe (Hungary, Serbia and Italy) in 2012 and 2013 as the result of high temperatures and drought. Mycological testing and determination of aflatoxins revealed increased contamination of maize from the 2012 and 2013 harvests with *Aspergillus flavus* mould and aflatoxin B_1 (Dobolyi et al. 2013; Kos et al. 2013). Increased occurrence of aflatoxin M_1 was subsequently observed in cow's milk in the given countries which exceeded the stipulated hygiene limits of 0.05 ng·g^{-1} for milk and 0.025 ng·g^{-1} for baby food (Commission Regulation (EC) No. 1881/2006). The finding of aflatoxin M_1 in cow's milk was reported repeatedly in 2012 and 2013 by the Rapid Alert System for Food and Feed (RASFF) within a range of 0.072 – 0.183 ng·g^{-1} (RASFF 2016). This case was extremely similar to the increased occurrence of *Aspergillus flavus* and aflatoxin B_1 in northern Italy in 2003 and 2004, when temperatures rose to more than 35 °C in the summer, accompanied by extreme drought, and increased occurrence of aflatoxin M_1 was subsequently seen in cow's milk (Giorni et al. 2007). European food safety experts can be expected to continue to encounter increased occurrence of *Aspergillus flavus* and aflatoxin B_1, particularly in maize, though also in other food crops, in the near future.

Climate change and the alimentary transmission of tick-borne encephalitis

Climate change in Europe is accompanied by changes in the ecology of endemic ticks (*Ixodes ricinus* L.). A spread of ticks and tick-borne encephalitis (TBE) to higher altitudes was observed during the 1990s and was explained as a consequence of climate change (Lingren et al. 2000). Although the typical habitat of ticks are mixed and deciduous forests to an altitude of roughly 700 metres above sea level, ticks have also been recorded in the Styrian Alps at an altitude of 1 350 metres and in the Krkonoše Mountains at an altitude of 1 200 metres (Hubálek and Rudolf 2011). This significantly increases the risk of TBE infection as these mountain regions are popular recreation destinations. The effect of climate change on the tick population and, thereby, the occurrence of TBE has been proven (Tälleklint and Lindgren 1998; Lingren et al. 2000; Daniel et al. 2004). Analysis of the characteristic features of TBE in the Czech Republic has confirmed the impact of climate warming on the spread of this disease in Central Europe (Zeman and Beneš 2004; Kříž et al. 2015). If ticks infected with the tick-borne encephalitis virus (TBEV) attack goats or dairy cows on the pasture and suck their blood, the virus is inoculated into the wound. Initially, the virus reproduces in the hypodermis at the site of inoculation (Beneš 2009). It then attacks the cells of the immune system which carry the virus to the local lymph nodes where the virus subsequently reproduces. The virus gets into other organs, such as the liver, spleen and bone marrow, where it again replicates, through the blood (Kaiser 2012). At this stage, the virus circulates in the blood in large numbers and subsequently gets into the milk. It must be said that organic milk from cows and goats in the foothills is of extremely high quality, particularly in terms of its sensory properties, and contains low numbers of bacteria and cellular elements, and this can encourage the consumer to drink this milk unpasteurised. Consuming raw milk and dairy products made from raw milk contaminated by the TBEV leads to the occurrence of TBE in unvaccinated persons.

This claim is backed up by the following case histories. A textbook example is the occurrence of the first epidemic of tick-borne encephalitis with alimentary transmission described in Rožňava in Slovakia in 1951, during which more than 300 of the inhabitants of the town of Rožňava and two neighbouring villages suddenly fell ill within the space of a few days. The disease manifested itself as typical two-stage meningoencephalitis. Epidemiological investigation demonstrated an explosive epidemic of alimentary origin. An active search for mild forms of the disease found around 700 people infected, of which almost 300 were hospitalised. Further investigation determined that the disease was transmitted by means of the drinking of raw milk from infected animals. Certain milk suppliers had mixed goat's milks into cow's milk. The affected area is a natural source of tick-borne encephalitis, and infected ticks had attached themselves to livestock on the pasture, leading to the transmission of the TBEV (Janovská 2001).

TBE caused by consumption of unpasteurised goat's milk and cheese was found in the Austrian Alps in July 2008. The first person affected was a 43-year-old farmer who grazed his goats on the Alpine montane meadows in Vorarlberg at an altitude of 1 564 metres above sea level. The farmer produced cheeses made from unpasteurised goat's milk which he ate himself and sold to tourists. He was hospitalised with a non-bacterial inflammation of the urinary tract and symptoms of influenza and meningitis. The TBEV was confirmed in the patient by the ELISA serological method and by detection of specific IgM and IgG in the serum and effusion. In terms of case history, the fact that no ticks were found on the patient was important. The patient stated that he had eaten unpasteurised goat's and cow's milk and cheese around eight to eleven days before first noticing the given symptoms. Epidemiological tests were performed on another six people who had consumed the same cheese and milk as the farmer. A serological finding of tick-borne encephalitis was made in five of these people. A total of three people also had clinical symptoms; two people were asymptomatic. One person with negative serology had vomited immediately after consuming a dairy product. The TBEV was also confirmed in four pigs consuming goat products. This serological finding in pigs was not accompanied by clinical symptoms. None of the people affected had been preventively vaccinated against tick-borne encephalitis. The cheese had been made from milk from one goat and three cows. The TBEV was found in the serum of the goat, while all three cows were serologically negative. Further serological testing of the infected goat performed one month later did not produce a positive result. Another 105 goats from the same farm also did not test positive for infection. An epidemiological analysis showed that seven people were infected by cheese from a single goat consumed twelve days before the outbreak of the infection. Experiments have demonstrated that the TBEV can be transmitted through milk on the second and third day following infection of the animal, which lasts 3 – 7 days. The expansion of ticks and the TBEV to higher altitudes has been proven by observation (Holzmann et al. 2009).

The World Health Organisation recommends vaccinating all age categories in areas with a high occurrence of TBE which includes the Czech Republic. Anyone over the age of one year may be vaccinated if they are likely to spend any time in the countryside, by a river, in a garden or even in green areas in the town. The greatest risk of serious lasting consequences is in the age category above sixty years of age. The available vaccines also protect against the Siberian and Far Eastern types of tick-borne encephalitis (WHO 2016).

Conclusions

The observed impact of climate change should be seen as a challenge for food safety experts in terms of how the given situation should be handled, what preventative and protective measures should be prepared and implemented, and how the principles and rules of good hygiene practices, good agricultural practices and the implemented Hazard Analysis and Critical Control Points (HACCP) system should be updated.

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