Croatian Journal of Food Science and Technology
journal homepage: www.ptfos.unios.hr/cjfst/

Mini Review DOI: 10.17508/CJFST.2020.12.2.12

Food safety in the face of climate change: consequences for consumers

OLUWAWAPELUMI A. OYEDELE[1], MUIZ O. AKINYEMI[1], TIHOMIR KOVAČ[2], UKPAI A. EZE[3], CHIBUNDU N. EZEKIEL[1]*

[1]*Department of Microbiology, Babcock University, Ilishan Remo, Ogun State, Nigeria*
[2]*Department of Applied Chemistry and Ecology, Faculty of Food Technology Osijek, Josip Juraj Strossmayer University of Osijek, Franje Kuhača 18, Osijek, Croatia*
[3]*School of Life Sciences, Faculty of Health and Life Science, Coventry University, CVI 2DS, United Kingdom*

ARTICLE INFO

Article history:
Received: July 7, 2020
Accepted: July 29, 2020

Keywords:
climate change
drought
food safety
flood
ocean warming

ABSTRACT

Food safety encompasses the elimination of biological, chemical, and physical hazards along the food chain; however, climate change, an abnormal change in weather conditions, is a threat to food safety due to irregularities in the elements of weather essential for food production. Such factors include elevated atmospheric carbon (IV) oxide (CO_2), precipitation, rainfall, and temperature. Considering that the aim of food safety is to eliminate food hazards along the food chain, it is threatened by climate change in several ways, resulting in adverse effects such as severe consequences for livestock production, harmful algal bloom, mycotoxins (produced by mycotoxigenic fungi on crops), residues of pesticides and tenacious contaminants, and pathogenic microorganisms from contaminated water. These climate changes include landslides and avalanches, drought and extreme heat waves, drought, heavy precipitation, flooding and tropical storms, ocean warming, climate change related acidification, and changes in ocean salinity. Therefore, there is a great need to employ adaptive strategies such as the establishment of a food safety management programme which would expound on the need to detect food hazards in food as a result of climate change. This programme should include setting up awareness for consumers, the improvement of epidemiological surveillance, improved co-ordination among food safety organizations, public health officials, and veterinary officials, amongst others. Thus, to achieve the sustainable development goal two, of eradicating hunger, it is imperative to harness the strategies for reducing the food safety hazards associated with climate change.

Introduction

Food safety entails the conscious handling of food along its value chain, i.e. from production to preparation of food for consumption, in order to prevent contamination by biological (algae, bacteria, fungi, and parasites), chemical (additives, pesticides, microbial and plant toxins), and physical (fragments of stone, wood, and glass) hazards. The wholesomeness of food could be altered by these hazards, which contaminate food due to inadequacies in practices along its value chain, e.g. poor agricultural system, excessive application of chemicals, storage technology and technique, and poor handler hygiene. The aforementioned hazards and causes of contamination have been addressed in several literature examples (Davidson et al., 2017; Garcia et al., 2020; Lafarga et al., 2019; Saiful, Khan & Kim, 2018) and solutions have been proffered on how to make food safe for consumers (Davidson et al., 2017; Garcia et al., 2020; Lafarga et al., 2019; Uçar et al., 2016). However, climate change is an evolving problem that can threaten global food safety. (FAO, 2010; Smith and Fazil, 2019; Uçar et al., 2016).

*Corresponding author E-mail: chaugez@gmail.com

Climate change, an abnormal change of the weather conditions caused by greenhouse gas emissions and several human activities, is an emerging stressor that is experienced over short periods and/or after a long period of time (Brown et al., 2015; Herrera et al., 2016). Living beings, from humans down to microscopic organisms, are affected by climate change. From the wildfires in Australia to the 'Arctic-like' levels of temperature in North America, abnormal has become the new normal. These natural disturbances have been shown to have severe impacts ranging from distortion of the properties of the ecosystem to the emergence of new patterns in the incidence of microorganisms in food, soil, and water (Coyle et al., 2017). Elements of the climate such as temperature, precipitation, and rainfall play an enormous role in the production of food. However, the unpredictable rainfall cycles, the increase in mean annual temperatures, the increase in atmospheric carbon (IV) oxide (CO_2), and changes in precipitation patterns pose a big threat to various stages of the food chain (from production to consumption) (Uçar et al., 2016). Considering the alteration of ecosystems due to climate change and the possible emergence of new or adapted strains of food spoilage and virulent microorganisms (Tirado et al., 2010), the safety of food could therefore be at risk of "new" types of threats as a result of climate change.

Climate change, such as an irregular increase in temperatures (heat stress), has been shown to cause a significant direct impact on animal production, including their health, growth, and reproduction (Rust, 2019). Indirectly, the changes in the nutritional environment, such as the availability of livestock feeds and quantity and quality of livestock pastures and forage crops also affects animal production. Furthermore, climate change may affect the rate at which diseases and infections are transmitted between vertebrate animals and humans by increasing the transmission cycle of many vectors, as well as the range plus prevalence of vectors and animal reservoirs (Short et al., 2017). In addition, climate change may lead to the emergence of new zoonotic diseases due to the consumption of these animals by humans (FAO, 2010; Lake et al., 2012).

Likewise, climatic change encourages eutrophication (excessive nutrients like nitrogen and phosphorus in lakes, streams, and oceans), causing the growth of phytoplankton and increasing the frequencies of toxigenic algal bloom (Neil et al., 2012). The accumulation of these toxins by filter feeders such as molluscs can have severe health implications like paralytic shellfish poisoning, neurotoxic shellfish poisoning, and diarrhoeic shellfish poisoning of humans after consumption (Lake and Barker, 2018).

Another impact of climate change is the possible increase in infectious diseases, especially food and waterborne diseases, owing to the fact that foodborne pathogens are usually influenced by climate and weather variables (Lake, 2017; Smith and Fazil, 2019). Changes in the pattern of temperature, humidity, and rainfall aid the transmission of diseases (food and water-borne diseases) from contaminated crops and water to humans, likewise, extreme weather conditions such as flooding, drought, and hurricanes can affect the availability and quality of water (Miraglia et al., 2009). Correspondingly, climate change can have potential impacts on the microbial evolution and stress response, the emergence of pathogens and the proliferation of toxigenic fungi, thereby endangering human health (Thomas, 2017).

Therefore, it is imperative to ensure adaptive approaches that will mitigate the risks posed by climate change are implemented.

Interplay between climate change and food safety

Climate change is likely to have considerable impacts on food safety, both direct and indirect, placing consumers' health at risk (Lake and Barker, 2018). The pathways through which climate related factors may influence food safety include the change in temperature and precipitation patterns, increased frequency and intensity of extreme weather events, landslides and avalanches, ocean warming and acidification, and changes in the transport pathways of complex contaminants (Tirado et al., 2010). A summary of the factors and the hazards they pose to food safety is highlighted in Table 1.

The increase in temperature and changes in the patterns of rainfall have a considerable impact on the persistence and patterns of occurrence of bacteria, viruses, and parasites, as well as the toxins they produce and their corresponding foodborne illnesses. Additionally, extreme weather conditions such as flooding, drought, and hurricanes can exacerbate the transmission of foodborne pathogens and contaminants to humans. For example, excessive periods of precipitation, floods, and droughts can influence the availability and quality of water and the contamination of soils with heavy metals and pesticides (Boddy et al., 2016; Cissé, 2019; FAO, 2010; Lake and Barker, 2018; Miraglia et al., 2009; Rajkumar et al., 2013; van der Spiegel et al., 2012). The impact of climate change has been observed in the transmission of foodborne diseases such as cholera, campylobacteriosis, listeriosis, and salmonellosis globally (FAO, 2010; Herrera et al., 2016). For example, a study in Canada deduced that increased air and sea surface temperature, high precipitation, and flooding resulted in the increased burden of *Campylobacter* spp, *Listeria monocytogenes*, *Salmonella* spp, *Vibrio parahaemolyticus*, *Vibrio vulnificus* and *Escherichia coli* 0157:H7 (Smith and Fazil, 2019; Hellberg and Chu, 2015).

Moreover, increased temperature, drought, and increased CO_2 can have an enormous impact on the shift of mycotoxigenic fungi and the production of mycotoxins, thereby creating an increase in toxin accumulation in infested agri-food products. In particular, increased temperature and drought conditions could favour the infestation of crops by *Aspergillus flavus* in some regions and increase the risk of aflatoxin formation in the field and post field (Assunção et al., 2018; Medina et al., 2017a,b; Paterson & Lima, 2011; Rajkumar et al., 2013; Kovač et al., 2020a;b; Ayeni et al., 2020). Moreover, elevated CO_2 is likely to contribute to and enhance fungal colonization by *Aspergillus* and *Fusarium* species, thus increasing the production of mycotoxins in food crops. Additionally, the combined occurrence of drought and heat stress can have several effects between crops and fungal pathogens and endophytes that ranges from a shift in mycotoxigenic fungi and mycotoxins to severe plant stress. For example, in Northern Italy, in 2003, 2004 and 2012, it was discovered that the prolonged drought conditions and extreme elevated temperatures (> 35 °C) resulted in stressed maize plants that were more prone to fungal infestations and the conditions were conducive for a switch from *Fusarium verticillioides* and fumonisins to the contamination of maize grains with *A flavus* and aflatoxins (Giorni et al., 2007; Medina et al., 2017b). Considering the economic and health impacts of mycotoxin contamination in food crops, infestation of food crops with mycotoxigenic fungi due to climate change is a threat to food safety (Kovač et al., 2018).

Consequences of the interplay between climate change and food safety on consumers' health

The food safety hazards posed by climate change have several implications for human health. These implications include foodborne illnesses and diseases, emergence of zoonotic diseases, malnutrition, under-nutrition and stunted growth from alteration of nutrients in contaminated crops, mycotoxicoses, hepatocellular carcinoma, respiratory and digestive problems, seizures, lesions and skin irritation, fatalities in fish, mammals, and humans, and possibly death from inadequate food supply.

1. According to the WHO, about 600 million people in the world have fallen ill as a result of ingestion of contaminated foods, while about 420,000 die annually due to the same cause (WHO, 2018). Owing to this statistic, climate change could exacerbate the transmission of food- and water-borne pathogens such as *Escherichia coli*, *Staphylococcus aureus*, *Helicobacter pylori*, *Pseudomonas aeruginosa*, *Baccillus subtilis*, *Listeria monocytogenes*, *Toxoplasma gondii*, *Vibrio cholerae*, *Shigella flexneri*, *Mycobacterium bovis*, *Campylobacter jejuni*, *Clostridium difficile*, *Yersinia enterocolitica*, *Baccillus cereus*, *Clostridium botulinium*, and rotavirus, causing an increase in foodborne illnesses and diseases (FAO, 2010; Lake and Barker, 2018).
2. Furthermore, due to climate change, infections and diseases can occur from zoonotic agents like the Rift Valley fever virus (in multiple species of livestock and wildlife), the Nipah virus (bats and pigs), the Hendra virus (bats and horses), the Hantavirus (rodents), and the Lassa fever virus (FAO, 2010).
3. Additionally, the uptake of algal toxins such as microcystin can target the liver cells, causing great damage to the liver as well as the eye and upper tract respiratory tract irritation, rash, and gastrointestinal infections (Anderson, 2019; Gibble, Peacock and Kudela, 2016).
4. Moreover, exposure to mycotoxins like aflatoxins, citrinin, fumonisins, ochratoxins, and beauvericin in crops can cause diverse health effects that range from cancer (especially hepatocellular carcinoma and human esophageal cancer) to stunted growth, mutagenicity, and neural tube birth defects in new-borns whose mothers were exposed during pregnancy (Munkvold et al., 2018; Wielogorska et al., 2019; Wu and Santella, 2012).

Strategies to ensure food safety despite the uncontrollable climate change

Food safety is threatened by several risks posed by climate change and it has been speculated that responding to climate change will be one of the greatest issues of the century. Hence, the management of the risk is highly recommended to avoid unpredicted circumstances such as worldwide foodborne disease outbreak (IPCC, 2019).

Table 1. Food safety risks posed by climate change

Natural disasters caused by climate change	Objects targeted	Environmental effects	Food safety risks	References
Landslides and avalanches	Landfills, dams, rivers	Contamination of surface water and agricultural land with contaminants deposited by mud from landslides.	Contamination of water and soils by pathogenic organisms, including *Campylobacter* spp, *Listeria monocytogenes*, *Salmonella* spp, *Vibrio parahaemolyticus*, *Vibrio vulnificus* and *Escherichia coli* 0157:H7, crops are grown on contaminated soils posing a huge risk to consumers.	(Geertsema, Highland, & Vaugeouis, 2009; Marvin et al., 2013; Smith and Fazil, 2019; Hellberg and Chu, 2015)
Drought and heat waves	Crops, animals	Severe change in temperature can lead to the proliferation of mycotoxigenic fungi belonging to the genus *Aspergillus*, *Fusarium*, *Penicillium*, and talaromyces. Increased temperature can change the pattern of grazing in livestock. Severe aridity can reduce soil microorganisms.	Production of mycotoxins such as aflatoxins, fumonisins, ochratoxins, and beauvericin that could lead to mycotoxicoses. Greater exposure of animals to vectors and wildlife. Increase in animal diseases that can lead to increased use of veterinary drugs, especially antibiotics, thereby promoting resistance. Increased veterinary drug residues in meat from livestock. Soil microorganisms such as *Rhizobium* will reduce in soil, affecting Nitrogen fixation.	(FAO, 2010; Lesnikowski et al., 2013; A. Medina et al., 2017a; Moretti et al., 2014)
Floods and tropical storms	Agricultural lands in flood plains	Contamination of agricultural and pasture land due to the deposits of flood water containing contaminants like pesticide residues and heavy metals.	Uptake of contaminants by crops grown on the contaminated lands. Bioaccumulation of chemical contaminants in humans and animals that consume the contaminated crops.	(FAO, 2010; Miraglia et al., 2009; Wan et al., 2019)
Heavy precipitation	Freshwater animals and irrigated crops	Contact with freshwater containing runoff with pathogens, contaminants, and nutrients caused by heavy precipitation.	Contamination of irrigated crops with pathogens and contaminants. Infection of freshwater animals with pathogens.	(Bouzembrak and Marvin, 2019; Marvin et al., 2013)
Ocean warming and climate change related acidification, change in ocean salinity and precipitation	Marine and estuarine habitat.	Changes in the biochemical properties of water and water microflora, distortion of the distribution of fisheries and the metabolic rate of fish, changes in the occurrence of pathogenic *Vibrio species*, harmful algal bloom and chemical contaminants in fish and shell fish.	Human illnesses such as amnesic shellfish poisoning, diarrhoeic shellfish poisoning, neurotoxin shellfish poisoning, paralytic shellfish poisoning, and ciguatera fish poisoning could be the result of consumption of seafood animals.	(Cavicchioli et al., 2019; Tirado et al., 2010)

Therefore, it is very important to employ food safety management programs like One Health that harness experts on food safety, public health, animal health, plant health and environment to mitigate the consequences of climate change (Garcia et al., 2020). In addition, improving the capacity to detect and to control rising foodborne hazards at all phases of the food chain will require efforts in various sectors, including the application of new scientific methods and tools that will be helpful in the characterization of complex microbial communities.

Furthermore, creating awareness by food safety and environment experts on adapting to climatic change along the food value chain will be helpful. Food organizations should ensure that consumers are properly informed on the effects of climate change on food safety by creating awareness in the media. Likewise, awareness programs should be set up by food production companies in collaboration with the WHO and the FAO for the consumers of their products, explaining meticulously the foodborne risks and hazards of the consumption of contaminated products (WHO, 2018).

Furthermore, there is a need to employ novel epidemiological surveillance that will help in early recognition of materializing food and water borne diseases. There should be rapid investigations of unusual outbreaks, alongside environmental investigation, to determine if the outbreaks are associated with climate change. Universal approach to epidemiological surveillance should be taken, since humans do not respect the boundaries (climate change). Also, public health organizations should be quick to mobilize and acknowledge emerging and resurfacing diseases of infectious origin (Calzadilla et al., 2013).

Likewise, there is a great need for enhancing the communication amongst health professionals, veterinary doctors, and environmental health workers, to provide valuable prediction and mitigation impact of climate change on infectious diseases, particularly foodborne diseases. The combined effect of each health officer will lead to a more productive solution for the global challenge (climate change) (Lake and Barker, 2018).

Lastly, the protection of the ecosystem is strongly advised, because this helps in the management of the risk to the barest minimum. This could be done by the protection of coastal areas from cyclones and other coastal hazards, the preservation of mangroves and their contribution to coastal fisheries, the use of degraded or marginal lands for productive planted forests or other cellulose biomass for alternative fuels, watershed protection; prevention of land degradation and conservation (WHO, 2018).

Conclusion

The environmental effects of climate change may have a colossal impact on the incidence and the types of hazards contaminating food, considering the alteration of the human and microbial ecosystems. Therefore, there is a vital need to employ awareness programmes on the impact of climate change on food safety, epidemiological surveillance to ascertain to what extent changes have occurred in the behaviour of microorganisms, and the use of eco-friendly technologies in view of protecting the environment and ensuring consumer health. Employing these aforementioned strategies will help in mitigating the several consequences of climate change on food safety.

Declaration of conflict of interest: The authors declare no financial or non-financial conflicts of interest.

Author contributions: CNE and OAO conceived the idea; CNE, OAO, OMA, TK and UAE wrote the manuscript. All authors read and approved the final manuscript.

References

Anderson, D. M. (2019): Harmful algal blooms. In *Encyclopedia of Ocean Sciences*. https://doi.org/10.1016/B978-0-12-409548-9.11468-X.

Assunção, R., Martins, C., Viegas, S., Viegas, C., Jakobsen, L. S., Pires, S. & Alvito, P. (2018): Climate change and the health impact of aflatoxins exposure in Portugal–an overview. *Food Additives and Contaminants - Part A Chemistry, Analysis, Control, Exposure and Risk Assessment* 35 (8), 1610–1621. https://doi.org/10.1080/19440049.2018.1447691.

Ayeni, K.I., Akinyemi, O.M., Kovač, T., Ezekiel, C.N. (2020): Aflatoxin contamination of maize vended in Ondo state, Nigeria and health risk assessment. *Croat. J. Food Sci. Technol.* 12 (1), 123-129. https://doi.org/10.17508/CJFST.2020.12.1.16

Boddy, L., Büntgen, U., & Kauserud, H. (2016): Climate impacts on fungal community and trait dynamics. *Fungal Ecology*. https://doi.org/10.1016/j.funeco.2016.03.005.

Bouzembrak, Y. & Marvin, H. J. P. (2019): Impact of drivers of change, including climatic factors, on the occurrence of chemical food safety hazards in fruits and vegetables: A Bayesian Network approach. *Food Control*. https://doi.org/10.1016/j.foodcont.2018.10.021.

Brown, M. E., Antle, J. M., Backlund, P., Carr, E. R., Easterling, W. E., Walsh, M. K., Tebaldi, C. (2015): *Climate Change, Global Food Security, and the U.S. Food System*. (September), 146. https://doi.org/10.7930/J0862DC7.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J. & Ringler, C. (2013): Economywide impacts of climate change on agriculture in Sub-Saharan Africa. *Ecological Economics*. https://doi.org/10.1016/j.ecolecon.2013.05.006.

Cavicchioli, R., Ripple, W. J., Timmis, K. N., Azam, F., Bakken, L. R., Baylis, M., Webster, N. S. (2019): Scientists' warning to humanity: microorganisms and climate change. *Nature Reviews Microbiology* 17 (9), 569–586. https://doi.org/10.1038/s41579-019-0222-5.

Cissé, G. (2019): Food-borne and water-borne diseases under climate change in low- and middle-income countries: Further efforts needed for reducing environmental health exposure risks. *Acta Tropica* 194 (April), 181–188. https://doi.org/10.1016/j.actatropica.2019.03.012.

Coyle, D. R., Nagendra, U. J., Taylor, M. K., Campbell, J. H., Cunard, C. E., Joslin, A. H., Callaham, M. A. (2017): Soil fauna responses to natural disturbances, invasive species, and global climate change: Current state of the science and a call to action. *Soil Biology and Biochemistry*. https://doi.org/10.1016/j.soilbio.2017.03.008.

Davidson, R. K., Antunes, W., Madslien, E. H., Belenguer, J., Gerevini, M., Davidson, R. K., Perez, T. T. (2017): *From food defence to food supply chain integrity*. https://doi.org/10.1108/BFJ-04-2016-0138.

FAO. (2010): Climate change: implications for food safety. *Fao*. https://doi.org/10.1146/annurev-ento-120709-144746.

Garcia, S. N., Osburn, B. I. & Jay-Russell, M. T. (2020): One Health for Food Safety, Food Security, and Sustainable Food Production. *Frontiers in Sustainable Food Systems* 4 (January), 1–9. https://doi.org/10.3389/fsufs.2020.00001.

Geertsema, M., Highland, L. & Vaugeouis, L. (2009): Environmental impact of landslides. *Landslides - Disaster Risk Reduction* (1), 589–607. https://doi.org/10.1007/978-3-540-69970-5_31.

Gibble, C. M., Peacock, M. B. & Kudela, R. M. (2016): Evidence of freshwater algal toxins in marine shellfish: Implications for human and aquatic health. *Harmful Algae* 59, 59–66. https://doi.org/10.1016/j.hal.2016.09.007.

Giorni, P., Magan, N., Pietri, A., Bertuzzi, T., & Battilani, P. (2007): Studies on Aspergillus section Flavi isolated from maize in northern Italy. *International Journal of Food Microbiology* 113 (3), 330–338. https://doi.org/10.1016/j.ijfoodmicro.2006.09.007.

Hellberg, R. S. & Chu, E. (2015): Effects of climate change on the persistence and dispersal of foodborne bacterial pathogens in the outdoor environment: A review. Critical Reviews in Microbiology 1–25. doi:10.3109/1040841x.2014.972335.

Herrera, M., Anadón, R., Iqbal, S. Z., Bailly, J. D. & Ariño, A. (2016): Climate change and food safety. In *Food Safety: Basic Concepts, Recent Issues, and Future Challenges*. https://doi.org/10.1007/978-3-319-39253-0_8.

Kovač, T., Borišev, I., Kovač, M. et al. (2020): Impact of fullerol C_{60} $(OH)_{24}$ nanoparticles on the production of emerging toxins by *Aspergillus flavus*. *Sci Rep* 10, 725. https://doi.org/10.1038/s41598-020-57706-3.

Kovač, T., Šarkanj, B., Borišev, I., Djordjevic, A., Jović, D., Lončarić, A. & Krska, R. (2020): *Fullerol C60(OH)24* Nanoparticles Affect Secondary Metabolite Profile of Important Foodborne Mycotoxigenic Fungi In Vitro. *Toxins* 12 (4), 213. https://doi.org/10.3390/toxins12040213.

Kovač, M., Šubarić, D., Bulaić, M., Kovač, K. & Šarkanj, B. (2018): Yesterday masked, today modified; what do mycotoxins bring next? *Archives of Industrial Hygiene and Toxicology* 69 (3), 196-214. https://doi.org/10.2478/aiht-2018-69-3108.

Lafarga, T., Colás-medà, P., Abadías, M., Aguiló-aguayo, I. & Bobo, G. (2019): Strategies to reduce microbial risk and improve quality of fresh and processed strawberries : A review. *Innovative Food Science and Emerging Technologies* 52 (May 2018), 197–212. https://doi.org/10.1016/j.ifset.2018.12.012.

Lake, I. R. & Barker, G. C. (2018): Climate Change, Foodborne Pathogens and Illness in Higher-Income Countries. *Current Environmental Health Reports*. https://doi.org/10.1007/s40572-018-0189-9.

Lake, Iain R., Hooper, L., Abdelhamid, A., Bentham, G., Boxall, A. B. A., Draper, A., Waldron, K. W. (2012): Climate change and food security: Health impacts in developed countries. *Environmental Health Perspectives*. https://doi.org/10.1289/ehp.1104424.

Lake, Iain, R. (2017): *Food-borne disease and climate change in the United Kingdom*. 16 (Suppl 1). https://doi.org/10.1186/s12940-017-0327-0.

Lesnikowski, A. C., Ford, J. D., Berrang-Ford, L., Barrera, M. & Heymann, J. (2013): How are we adapting to climate change? A global assessment. *Mitigation and Adaptation Strategies for Global Change*. https://doi.org/10.1007/s11027-013-9491-x.

Marvin, H. J. P., Kleter, G. A., Van der Fels-Klerx, H. J., Noordam, M. Y., Franz, E., Willems, D. J. M. & Boxall, A. (2013): Proactive systems for early warning of potential impacts of natural disasters on food safety: Climate-change-induced extreme events as case in point. *Food Control*. https://doi.org/10.1016/j.foodcont.2013.04.037.

Medina, A., Akbar, A., Baazeem, A., Rodriguez, A. & Magan, N. (2017a): Climate change, food security and mycotoxins: Do we know enough? *Fungal Biology Reviews* 31 (3), 143–154. https://doi.org/10.1016/j.fbr.2017.04.002.

Medina, Á., González-Jartín, J. M. & Sainz, M. J. (2017b): Impact of global warming on mycotoxins. *Current Opinion in Food Science* 18, 76–81. https://doi.org/10.1016/j.cofs.2017.11.009.

Miraglia, M., Marvin, H. J. P., Kleter, G. A., Battilani, P., Brera, C., Coni, E., Vespermann, A. (2009): Climate change and food safety: An emerging issue with special focus on Europe. *Food and Chemical Toxicology* 47 (5), 1009–1021. https://doi.org/10.1016/j.fct.2009.02.005.

Moretti, A., Pascale, M., Logrieco, A. F., Ojuri, O. T., Ezekiel, C. N., Sulyok, M., Garcia-Casal, M. N. (2014): Limited survey on aflatoxin contamination in rice. *Food Control* 26 (1), 1–13. https://doi.org/10.1016/j.sjbs.2017.05.010.

Munkvold, G. P., Arias, S., Taschl, I. & Gruber-Dorninger, C. (2018): Mycotoxins in corn: Occurrence, impacts, and management. In *Corn: Chemistry and Technology 3rd Edition* (3rd ed.). https://doi.org/10.1016/B978-0-12-811971-6.00009-7.

Neil, J. M. O., Davis, T. W., Burford, M. A. & Gobler, C. J. (2012): The rise of harmful cyanobacteria blooms : The potential roles of eutrophication and climate change. *Harmful Algae* 14, 313–334. https://doi.org/10.1016/j.hal.2011.10.027.

Paterson, R. R. M. & Lima, N. (2011): Further mycotoxin effects from climate change. *Food Research International*. https://doi.org/10.1016/j.foodres.2011.05.038.

Rajkumar, M., Prasad, M. N. V., Swaminathan, S. & Freitas, H. (2013): Climate change driven plant-metal-microbe interactions. *Environment International*. https://doi.org/10.1016/j.envint.2012.12.009.

Rust, J. M. (2019): The impact of climate change on extensive and intensive livestock production systems. *Animal Frontiers* 9 (1), 20–25. https://doi.org/10.1093/af/vfy028.

Saiful, M., Khan, I. & Kim, Y. (2018): PT of Korea. *Innovative Food Science and Emerging Technologies*, #pagerange#. https://doi.org/10.1016/j.ifset.2018.11.011.

Short, E. E., Caminade, C. & Thomas, B. N. (2017): Climate Change Contribution to the Emergence or Re-Emergence of Parasitic Diseases. *Infectious Diseases: Research and Treatment* 10. https://doi.org/10.1177/1178633617732296.

Smith, B. & Fazil, A. (2019): How will climate change impact microbial foodborne disease in Canada? *Canada Communicable Disease Report* 45 (4), 108–113. https://doi.org/10.14745/ccdr.v45i04a05.

Thomas, F. (2017): Climate change and health. In *Encyclopedia of the Anthropocene*. https://doi.org/10.1016/B978-0-12-809665-9.09791-3.

Tirado, M. C., Clarke, R., Jaykus, L. A., McQuatters-Gollop, A. & Frank, J. M. (2010): Climate change and food safety: A review. *Food Research International*. https://doi.org/10.1016/j.foodres.2010.07.003.

Uçar, A., Yilmaz, M. V. & Çakiroglu, F. P. (2016): Food Safety – Problems and Solutions. *Significance, Prevention and Control of Food Related Diseases* 1–26. https://doi.org/10.5772/63176.

van der Spiegel, M., van der Fels-Klerx, H. J. & Marvin, H. J. P. (2012): Effects of climate change on food safety hazards in the dairy production chain. *Food Research International*. https://doi.org/10.1016/j.foodres.2011.12.011.

Wan, Y., Huang, Q., Camara, A. Y., Wang, Q. & Li, H. (2019): Water management impacts on the solubility of Cd, Pb, As, and Cr and their uptake by rice in two contaminated paddy soils. *Chemosphere* 228, 360–369. https://doi.org/10.1016/j.chemosphere.2019.04.133.

Wielogorska, E., Mooney, M., Eskola, M., Ezekiel, C. N., Stranska, M., Krska, R. & Elliott, C. (2019): Occurrence and Human-Health Impacts of Mycotoxins in Somalia [Research-article]. *Journal of Agricultural and Food Chemistry* 67 (7), 2052–2060. https://doi.org/10.1021/acs.jafc.8b05141.

Wu, H. C. & Santella, R. (2012): The role of aflatoxins in hepatocellular carcinoma. *Hepatitis Monthly* 12 (10 HCC), 1–9. https://doi.org/10.5812/hepatmon.7238.

World Health Organization (2018): Food safety climate change and the role of WHO. Department of Food safety and zoonoses.