Discussion and key conclusions

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The UK climate can impact the risk of pathogenic contamination in the food sector. Extreme weather events such as increased rainfall and flooding, drought, and heatwaves can influence how pathogens spread, grow, and contaminate food sources. Certain food sectors, particularly those dealing with fresh produce (e.g., crops, meat, seafood, dairy produce), are vulnerable to pathogens due to their direct exposure to environmental factors. Therefore, food sectors may need to upgrade or amend their existing control protocols to anticipate increased pathogen risks due to climate change. This discussion will explore the key food categories at risk, the associated pathogens, and the underlying causes contributing to the sector-specific risks during extreme weather conditions (flooding, drought, and heatwaves).

Flooding

Flooding is defined as an overflow of water that submerges land which is usually dry; caused by heavy rainfall, river and costal overflow, dam breakage or overwhelmed drainage systems (1). Flooding can increase the risk of pathogen contamination in several ways. The participants highlighted that heavy rainfall, and flooding can lead to the contamination of water supplies used for irrigation in agricultural fields. Runoff from nearby livestock farms, where animal manure is used as fertiliser, can introduce pathogens such as VTEC/STEC, *Salmonella*, and *Campylobacter* into fields of crops, particularly leafy greens. The contaminated water may splash onto crops during irrigation or heavy downpours, spreading pathogens directly onto produce which is a particular concern for fruits and vegetables that can be consumed raw.

During flooding, contamination of rivers and lakes with sewage or animal waste is common. Floodwaters can also spread pathogens such as viruses (HepA, HepE), bacteria (Salmonella, *Listeria*, E.coli) as well as parasites such as Cryptosporidium (not included in the workshop exercise). Therefore, crops may be directly or indirectly contaminated via irrigation or floodwater. Livestock farms (poultry and beef) may also experience wet and muddy conditions during flood events. This can lead to poor animal hygiene, increasing the likelihood of contamination of animal-derived food products. The participants highlighted for example, mud and faecal matter on farms can introduce *Salmonella* and VTEC/STEC into dairy and meat products during the milking or slaughter process. This is particularly problematic in the UK during the rainy seasons when farm conditions are challenging to manage.

The participants also highlighted that shellfish, particularly filter feeders (mussels and oysters), are vulnerable are vulnerable to waterborne contamination in coastal regions after floods due to sewage overflow incidents. This can introduce the emergence of bacteria such as VTEC/STEC and viruses into shellfish supply. This can pose a significant risk to consumers, especially when shellfish is eaten raw or undercooked.

Drought

Drought is typically defined as an extended period of significant below-average rainfall, leading to a shortage of water (2) Drought conditions can significantly impact the food sector by creating environments that facilitate the emergence and spread of pathogens. While drought may seem like a situation where moisture-related pathogens might be less of a concern, the indirect effects of drought can increase the risk of contamination in several ways. The participants

highlighted that droughts create a limited access to clean, fresh water for agricultural purposes. This may lead to an increased reliance on untreated or recycled water for irrigation and farming. Untreated or recycled water may carry a higher pathogen load, including bacteria such as VTEC/STEC, *Salmonella* and *Listeria* which can contaminate crops or the soil in which they grow.

Moreover, the participants discussed how livestock health may be affected during a period of reduced availability of clean water and feed. Firstly, a lack of water can create unsanitary conditions due to inadequate disinfection processes, promoting the growth and spread of pathogens. This may increase the likelihood of contamination during milking or slaughter. The participants suggested that bacteria such VTEC/STEC, *Salmonella* and *Listeria* have the potential to emerge as a risk for livestock and dairy products due to the potential for contamination. This is of particular concern for raw milk and raw milk cheeses as these have more limited control measures to eliminate pathogens that may be present. Furthermore, during drought livestock may experience stress and malnutrition, leading to stress. Stressed and undernourished animals are more susceptible to infections and disease. Therefore, the participants proposed pathogens such as *Campylobacter* and *Salmonella* could be a risk for poultry.

Heatwave

Heatwaves are defined as a prolonged period of unusually hot weather, often accompanied by high humidity (3) Heatwaves can have a profound impact on the food sector by promoting the emergence and spread of pathogens through various mechanisms, including faster bacterial growth (especially within processing environments), disruptions to refrigeration systems (cold chain infrastructure), increased need for import following higher mortality rates in livestock, and riskier consumer behaviour. The reasoning of the participants was that during heatwaves, there is an increased demand for electricity (air conditioning and cooling systems) which may lead to power outages or energy shortages. When refrigeration fails, perishable chilled foods are exposed to higher temperatures, allowing pathogens to multiply. Even short periods of exposure to temperatures above refrigeration thresholds can lead to growth of pathogen microorganisms.

Conclusion

Different food sectors will face significant challenges during severe weather conditions that may lead to the emergence of microbiological concerns in food

products reaching consumer. The participants identified crops, and RTE fruit and vegetables as the most vulnerable sectors to microbial contamination during flooding, drought, and heatwaves. The participants highlighted that VTEC/STEC are the contaminating microorganisms that pose the most significant risk to crops, and RTE fruit and vegetables during flooding and drought. This is due to the increased potential for insufficient and unsanitary farming practices and a lack of adequate processing during the extreme weather events to eliminate the contaminating pathogens. However, *Listeria* was found to pose the most significant risk to chilled food during a heatwave. The reasoning behind this emerging risk included disruptions to the cold chain systems. However, other food sectors (poultry, beef, fish, shellfish, dairy, and imported eggs) are also at risk of emerging microbiological issues because of severe weather conditions due to environmental factors, the potential for insufficient hygiene practices, reliance on infrastructure (cold chain) and livestock health (e.g., malnutrition, stress). Therefore, monitoring the emergence of microbes during adverse weather and identifying opportunities for mitigation will help provide security for robust food sectors.