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Impact of Climate Change on Microbiological Hazards in Food and Drinking Water in Sweden

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Authors' contributions

All authors were involved with drafting the main report and the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Objective and scope: To increase our knowledge on how climate change can affect microbiological food safety in Sweden, during this century, a risk profile was developed. The focus of the report is to identify existing and emerging microbiological hazards (pathogenic microorganisms and toxins) that may be of concern and may affect the safety of food and water consumed in Sweden. Specific issues addressed are how the different stages in the food chain can be affected, and which hazards are most relevant for different food groups. The report is based on published scientific literature and governmental reports.

Climate change scenarios: Human emissions of carbon dioxide and other greenhouse gases affect a range of climate-related factors and lead to changes beyond those natural variations that have always occurred. These climate changes are already evident and will, according to various scenarios, continue during the rest of the century. The scenario assessed in the report was RCP8.5. Globally, this means higher annual average temperatures, changing precipitation patterns, reduced access to freshwater in many regions, rising sea levels, and acidification of the oceans. In Sweden, the climate will become warmer compared to today, especially in winter. Rainfall will generally increase, mostly in winter and spring, especially in the northern parts of Sweden. In the southeastern part of the country, increased drought and water shortages are expected. Climate change is also expected to lead to more frequent extreme weather, for instance floods and heat waves.

Impact on food safety: A changed climate will have several effects on the environment and society that can affect food safety. Examples of such effects are changing conditions for crop production, livestock production, infrastructure, energy supply, and water availability.

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Climate change can influence food safety in different ways and through different routes along the entire food chain. Much of the impact occurs at the first stage, primary production, and can then propagate in the rest of the chain. Two scenarios were highlighted in the report, both of which are relevant for all stages of the food chain, although they may be of varying importance depending on the stage and type of operation considered:

- The first scenario includes the impact on food safety due to a change in the normal conditions with higher average temperature, increased precipitation or drought, and milder winters.
- The second scenario includes an increased frequency of extreme events such as torrential rains, floods, and dry periods, with potential consequences such as power failures and other disruptions of infrastructure that can have a major impact on the food chain and, in turn, on food safety.

Climate change adaptations: In order to address the challenges associated with new "normal conditions", climate change adaptation is needed in the production chains of food and drinking water. The normal conditions in Sweden may become similar to the current situation in southern Europe. This description of the new potential situation in this scenario is useful for communication purposes, and gives the stakeholders an idea of what adaptation measures may be needed.

Additionally, an increased preparedness is needed to prevent and manage extreme events in the second scenario that can lead to an increased occurrence of pathogens and toxins in the raw materials and in drinking and process water as well as to increased frequency of disturbances in infrastructure.

To some extent, changed conditions in primary production can be addressed through the application of Good Agricultural Practice and/or certification standards. However, despite these frameworks, the challenges in this first stage of the food chain can be expected to be particularly high. It is more difficult to implement direct management measures here than at later stages of the food chain. There, HACCP-based procedures and PRPs such as good hygiene practices and good production practices have been used with good results.

Microbiological hazards: Assessing the impact of climate change on microbiological hazards is complex. This is partly because the changes that will take place are interrelated and can affect our environment in several different ways. It is also due to the fact that the available studies on which the assessment is based vary greatly, both in terms of the hazards that are studied and in terms of scope and methodological designs.

Bacteria that are likely to increase in the environment, water, animals, plants, and/or food raw materials due to a changing climate, and for which the level of evidence is considered high, are *Bacillus anthracis*, *Francisella tularensis*, *Salmonella* spp., *Shigella* spp., and *Vibrio* spp. Potentially, all food-borne viruses are expected to increase in occurrence due to climate change. However, the level of evidence is intermediate for noroviruses and low for hepatitis A virus and hepatitis E virus. Most parasites will potentially increase in occurrence due to climate change, but the level of evidence is low for most. For *Cryptosporidium* spp., *Giardia intestinalis*, and *Toxoplasma gondii*, the level of evidence is intermediate. Among the mycotoxins, it is estimated that all Fusarium toxins addressed (DON, T2/HT2, ZEN, and fumonisins) will increase, of which the evidence level is highest for DON and fumonisins. Further, aflatoxins are expected to increase with a high level of evidence. In addition to the microbiological hazards listed, several other species of bacteria, viruses, and parasites as well as types of mycotoxins are also considered likely to increase, but due to a lack of data and in some cases conflicting indications, these assessments are uncertain.

None of the microbiological hazards discussed in the report have been assessed likely to decrease in occurrence due to climate change. However, it should be noted that some climatic factors may influence microbiological hazards in both positive and negative directions. At the local level, it may thus be the case that certain hazards that have been assessed as potentially increasing instead remain unchanged or even decrease in occurrence. The final outcome also depends on the effectiveness of measures taken to address the challenges of climate change.

Microbiological hazards and food groups: The microbiological hazards increasing in importance due to a changing climate are likely to vary for different food groups. The pathogenic microorganisms and toxins judged potentially to increase in occurrence and of relevance in different food groups due to a changed climate have been compiled (Table 1). It has not been possible, on the basis of existing data, to rank the hazards. The assessment suggests that it is of greatest importance to consider which pathways and types of hazards (properties, resistance) may be relevant in the different food groups because the control measures will in most cases be similar for different types of hazards.

Table 1. Microbiological hazards that may be important in different food groups in a changing climate. For justifications and details on the importance of the different hazards, see the main report, chapter 6

Food group	Microbiological hazards that may have a potentially increased occurrence in the environment, water, animals, plants, and/or food raw materials due to a change in climate
Dairy	*Campylobacter* spp., *Salmonella* spp., shigatoxin-producing *E. coli* (STEC) and other pathogenic *E. coli*, *Listeria monocytogenes*, *Yersinia* spp., tick-borne encephalitis virus (TBE), *Toxoplasma gondii*, *Cryptosporidium parvum*, aflatoxin M1
Meat	*Salmonella* spp., *Campylobacter* spp., STEC, *Yersinia enterocolitica*, Hepatitis E virus (HEV), *Trichinella* spp., *Toxoplasma gondii*
Eggs	*Salmonella* spp., STEC and other pathogenic *E. coli*, *Campylobacter* spp., *Bacillus cereus*, *Staphylococcus aureus*
Cereal products	*Salmonella* spp., STEC and other pathogenic *E. coli*, deoxynivalenol, T2 and HT2, zearalenone, aflatoxins, fumonisins, ochratoxin A, ergot alkaloids
Fruits, berries and vegetables	*Salmonella* spp., *Shigella* spp., STEC, *Listeria monocytogenes*, Norovirus, Hepatitis A virus (HAV), *Cryptosporidium parvum*, *Cyclospora cayetanensis*, patulin
Vegetable oils, nuts and seeds	*Salmonella* spp., STEC and other pathogenic *E. coli*, aflatoxins
Drinking water	*Campylobacter* spp., STEC and other pathogenic *E. coli*, *Francisella tularensis*, *Salmonella* spp., *Shigella* spp., *Vibrio cholerae*, Norovirus, Sapovirus, HAV, Adenovirus, Astrovirus, Rotavirus, *Cryptosporidium* spp., *Entamoeba histolytica*, *Giardia* spp., *Cyclospora cayetanensis*
Seafood	*Vibrio* spp. (*Vibrio parahaemolyticus*), *Listeria monocytogenes*, *Clostridium botulinum*, *Aeromonas hydrophila*, *Salmonella* spp., *Campylobacter* spp., STEC and other pathogenic *E. coli*, *Shigella* spp., *Yersinia enterocolitica*, Norovirus, HAV

Concluding remarks: Many sources of uncertainty for the assessments were identified. The main sources include knowledge gaps associated with data on the extent to which the climate will impact on microbiological hazards, difficulties in identifying causal relationships based on correlations, knowledge gaps associated with the methodology of carrying out this type of complex assessment against uncertain future scenarios, and knowledge gaps regarding the future climate and its effects. A further contributing uncertainty is knowledge gaps on potential feedback mechanisms between climate change and its effects.

Despite the uncertainties, the increased food safety challenges qualitatively identified in this report are considered likely. These challenges are the consequences of the impacts that climate change under the RCP8.5 scenario may have on several of the microbiological hazards in terms of increased or potentially increased occurrence in the environment, water, animals, plants, and/or food raw materials. Conclusions on the change of specific microbiological hazards, the extent of the impact, and the rate of change are subject to significantly greater uncertainty. This is not least because the impact of climate change depends on the accuracy of the climate scenarios and on what measures are put in place.

The risk profile is an initial and general compilation of knowledge that can form a basis for further and more detailed studies and activities in the various sectors in the food chain.

The complete report can be downloaded from:

L 2021 — No 19 — Microbiological hazards (livsmedelsverket.se).

Keywords: Risk profile; food safety; dairy; meat; cereals; fruits; vegetables; seafood.

ABBREVIATIONS

HACCP: *Hazard Analysis and Critical Control Points. Food safety management system based on the HACCP principles. System for identifying, assessing and controlling hazards relevant to food safety in a business activity.*

PRP: *Prerequisite programmes. All food businesses must have in place prerequisite programmes (PRPs). These are good hygiene practices that are the basic conditions and activities necessary to maintain a hygienic environment.*

RCP: *A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. Four pathways were used for climate modelling and research, and describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come. The RCPs are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m2, respectively).*

Risk profile: *A description of a food safety problem and its context in order to identify those elements of the hazard or risk relevant to various risk management decisions.*

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COMPETING INTERESTS

Authors have declared that no competing interests exist.