How will climate change impact microbial foodborne disease in Canada?

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Abstract

Foodborne disease is a major concern in Canada and represents a significant climate change-related threat to public health. Climate variables, including temperature and precipitation patterns, extreme weather events and ocean warming and acidification, are known to exert significant, complicated and interrelated effects along the entire length of the food chain. Foodborne diseases are caused by a range of bacteria, fungi, parasites and viruses, and the prevalence of these diseases is modified by climate change through alterations in the abundance, growth, range and survival of many pathogens, as well as through alterations in human behaviours and in transmission factors such as wildlife vectors. As climate change continues and/or intensifies, it will increase the risk of an adverse on food safety in Canada ranging from increased public health burden to the emergence of risks not currently seen in our food chain. Clinical and public health practitioners need to be aware of the existing and emerging risks to respond accordingly.

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Introduction

Many of the recently observed climate changes have been unprecedented over the preceding decades to millennia (1,2). The projected changes to climate variables in Canada, including temperature and precipitation metrics, are well-documented (3). In particular, annual average air and water temperatures and precipitation are expected to rise across the country, with regional and seasonal variations (4). Already the consequences of climate change within Canada are evident (2), and additional wide ranging and significant effects on many areas are expected, including on the prevalence of foodborne diseases. The World Health Organization recently released a report estimating the burden of foodborne illnesses caused by 31 hazards (bacteria, viruses, parasites, toxins and chemicals), where they estimated that, worldwide, these hazards caused 600 million foodborne illness and 420,000 deaths in 2010 (5). In Canada alone, there were an estimated four million cases of microbial foodborne diseases per year in the time period from 2000 to 2010 (6). Hence, an increase in cases of foodborne disease due to climate change would exacerbate an already important public health concern in Canada.

Food safety, food security and food system challenges are thought to represent the most significant climate change-related threats to human health globally (7–12). Researchers anticipated a link between foodborne illness and climate change, since the pathogens that cause many foodborne infectious diseases are known to be influenced by climate and weather variables (13–21). Despite their obvious importance, these food safety issues have received little attention in the climate-health literature relative to other health indicators (12). The purpose of this paper is to provide a summary of how climate change will increase the risk of microbial foodborne diseases, and what can be done to address this.

Effect of climate change on foodborne illness

The climate variables that most influence foodborne illness are increased air temperature, water temperature and precipitation (13,14). These variables affect foodborne illness through three mechanisms: abundance, growth, range and survival of pathogens in crops, livestock and the environment (22); human exposure factors, including cooking practices, food handling and food preferences that are influenced by a longer period of warm temperatures; and transmission factors, such as wildlife vectors, that transfer pathogens to food.

Studies from regions with similar climate and seasonality to Canada have linked foodborne contamination and disease incidence with seasonal trends (13,14). These studies reported a strong association between increasing air and water temperatures and an altered and extended summer season for non-cholera *Vibrio* species (spp.) infections. So strong was this sensitivity to climate that it was proposed that non-cholera *Vibrio* spp. can act as a barometer of climate change in marine systems (23). Similarly, a time-series analysis showed that rates of enteric illness varied seasonally within Canada, with a strong association between infections with *Campylobacter* spp., pathogenic *Escherichia coli* and *Salmonella* spp., and ambient air temperature (24). These results are generally similar to those reported from other countries (13–17,25,26).

The growth, survival, abundance and range of pathogens will be affected by climate change throughout the food chain. Growth and survival of pathogens is intrinsically linked to climate factors (often ambient temperature) (14); for example, survival of *E. coli* is dependent on temperature, moisture and interactions with the microbial community (27), with greater growth at higher temperatures, within limits (28). Livestock stressed at higher temperatures may shed greater amounts of enteric pathogens (29,30), affecting pathogen prevalence in crops, the environment and produce. Pathogens could expand their range and become established in new regions of Canada as climate conditions become more favourable for their growth. Precipitation events can move pathogens through the environment and contaminate food sources such as crops or livestock facilities.

Human exposure factors are also related to climate change. As the summer season lengthens, a greater number of food mishandling events leading to cross contamination or undercooking are anticipated. Increased food mishandling by consumers is due in part to differences in cooking preparation methods (e.g. barbeque, a commonly used cooking technique in the summer) or different consumption patterns (e.g. picnics) (18,31,32). Contamination of meat products with *Salmonella* spp. in Canada is similar throughout the summer season compared with the rest of the year (*unpublished data, BA Smith, National Microbiology Laboratory, Guelph, Ontario*), yet human cases of salmonellosis increase throughout this time of year in some regions (24,31). This suggests that human exposure factors drive salmonellosis rates (31), which themselves are driven by climate. Food preferences are likely to change due to increased food availability; for example, a lengthened summer growing season can result in more fresh produce consumption, which is also linked to foodborne illness (33,34).

Finally, climate change can impact foodborne illness indirectly, through increased activity, range expansion and reproduction rates of wildlife vectors (35). Wildlife vectors can transmit pathogens to food in a number of ways. The presence of rodents and insects, including beetles, flies and litterbugs, on farms is associated with increased *Campylobacter* spp. contamination in chicken broiler flocks (36). Produce such as lettuce or strawberries are generally grown in rural areas and fields are susceptible to intrusion of wildlife such as deer, which are known carriers of human pathogens (37,38). *Vibrio* ssp. can be transmitted to oysters in marine environments through phytoplankton, zooplankton and copepod vectors (39). The impact of climate change on each of these vectors can result in changes to foodborne contamination and disease.

Current and emerging foodborne illnesses

When the causative agent is identified, the five bacteria that account for over 90% of foodborne illnesses in Canada are norovirus, *Clostridium perfringens*, *Campylobacter* spp., *Salmonella* spp. and *Bacillus cereus* (**Table 1**) (6). Four of these pathogens have been shown to be influenced by climate variables. Given the projected changes to climate in Canada, it is anticipated that the overall burden from these and other pathogens will increase. Additional pathogens ranked lower in Canada (6), for which there is a known link between climate and foodborne diseases, are also included in Table 1. Although generalizations are apparent (e.g. an increase in extreme events, precipitation and temperature increases incidence of many foodborne diseases), the precise impact of climate change is pathogen- and commodity-specific. The incidence of *Vibrio* spp. has been linked to air temperatures, consumption practices and water temperatures (40,41) and it is anticipated that the relative ranking of *Vibrio* spp. will increase with climate change.

Other foodborne disease issues

There are other less common foodborne infections that are likely to increase with climate change and add to the burden to personal and public health. Mycotoxins, produced by fungi growing in crops such as corn and cereal grains, proliferate with increased air temperature, humidity and precipitation (45). Increased temperature stress or alterations to livestock housing conditions as a result of climate change could also drive increased antimicrobial use in food-producing animals, which might increase occurrence of antimicrobial-resistant foodborne illness in humans (46). Because climate change is a global issue, and because Canada imports a significant percentage of its foodstuffs especially in the winter months, impacts on contamination of imported foods with pathogens exotic to Canada are expected.

Clinical and public health response

The medical and public health systems as well as the public will need to prepare for the anticipated amplification in the rate of illness from known foodborne pathogens and the emergence of illness from either exotic or less well-known pathogens. Clinicians need to stay informed on foodborne illness trends to better recognize and diagnose cases and, when indicated, treat them in the light of known trends in antimicrobial resistance. Public health needs to prepare for more outbreaks. Laboratory capacity will need to increase to detect the increase in persistent as well as emerging infections. There will be a need for increased public awareness of this climate-related trend and the importance of good food safety practices. And as always, there will be a need for strengthening our surveillance systems to monitor changing trends to better understand the changing profile of illness and the distribution of animal reservoirs.

Table 1: Key foodborne pathogens currently ranked in Canada to consider in the context climate change (6)

Pathogen	Symptoms (42)	Current cases per 100,000 people (6)	Influence of climate on occurrence (20,43)
Norovirus	Symptoms include nausea, vomiting, diarrhea, stomach cramps, low-grade fever, chills, headache, muscle aches and fatigue	3,223.79	Extreme weather events (such as heavy precipitation and flooding) and decreased air temperature
Clostridium perfringens	Symptoms include diarrhea, pain and cramps, stomach bloating, increased gas, nausea, weight loss, loss of appetite, muscle aches and fatigue. In rare cases, severe dehydration, hospitalization, death	544.50	Uncertain
Campylobacter spp.	Symptoms include fever, nausea, vomiting, stomach pain, and diarrhea. In rare cases, hospitalization and long-lasting health effects, death	447.23	Changes in the timing or length of seasons, increased air temperatures, precipitation and flooding
Salmonella spp., nontyphoidal	Symptoms include chills, fever, nausea, diarrhea, vomiting, stomach cramps, and headache. In rare cases, hospitalization and long-lasting health effects, death	269.26	Changes in the timing or length of seasons, extreme weather events, increased air temperatures
Bacillus cereus	Symptoms include diarrhea or vomiting. In rare cases, hospitalization and long-lasting health effects, death	111.60	Changes in the timing or length of seasons, drought
Verotoxigenic *Escherichia coli* non-O157	Symptoms include diarrhea. In rare cases, hospitalization and long-lasting health effects, death	63.15	Changes in the timing or length of seasons, extreme weather events, increased air temperatures
Verotoxigenic *Escherichia coli* O157	Symptoms include diarrhea. In rare cases, hospitalization and long-lasting health effects, death	39.47	Changes in the timing or length of seasons, extreme weather events, increased air temperatures
Toxoplasma gondii	Symptoms include minimal to mild illness with fever. In rare cases, inflammation of the brain and infection of other organs, birth defects	28.10	Extreme weather events, increased air temperatures, precipitation (44)
Vibrio parahaemolyticus	Symptoms include diarrhea, stomach cramps, nausea, vomiting, fever and headache. In rare cases, liver disease	5.53	Extreme weather events, increased air temperatures, increased sea surface temperature
Listeria monocytogenes	Symptoms include fever, nausea, cramps, diarrhea, vomiting, headache, constipation, muscle aches. In severe cases, stiff neck, confusion, headache, loss of balance, miscarriage, stillbirth, premature delivery, meningitis, death	0.55	Extreme weather events, increased air temperatures, precipitation
Vibrio vulnificus	Symptoms include diarrhea, stomach cramps, nausea, vomiting, fever, headache. In rare cases, liver disease	<0.01	Extreme weather events, increased air temperatures, increased sea surface temperature

Abbreviations: spp., species; <, inferior to
Note: Currently, the five most common foodborne pathogens are norovirus, *Clostridium perfringens, Campylobacter spp., Salmonella spp. and Bacillus cereus*

Discussion

Climate change will increase the risks from existing and emerging foodborne diseases, primarily through increases in extreme events, increases in air and water temperatures, and changes to precipitation frequency and intensity. It is important to note, however, that these trends regarding foodborne illness and climate change involve complex systems with many interacting factors (47).

The impact of climate change on foodborne disease is not a linear relationship, as it involves modifiable risk factors. Efforts to minimize the incidence and impact of climate-related foodborne illness should focus on these modifiable factors through farm-level interventions such as vector control, processor interventions such as improved cleaning procedures and modifying human behaviours to promote food safety. Other factors will also impact the incidence of foodborne illness, including an aging and increasingly diverse population and changes to imported foods; many of these factors are themselves influenced by climate change, yet often not explicitly considered in climate change and food safety research.

Future directions

Cross-disciplinary research using various methodological tools can provide insight and forecast disease transmission patterns under specific climatic conditions (48). One promising example is mathematical modelling, as it can be used to provide better insights into the complexities of climate and infection interactions and allow for testing of various adaption or mitigation measures to counteract the negative impacts of climate change on food safety. Modelling studies apply a set of logical assumptions to predict, with an inevitable degree of uncertainty, how risks may develop in the future. A risk modelling framework specific to Canada has been developed (50). It provides a structured platform for constructive, transparent discussion around the state of knowledge on climate change impacts on food safety. The framework has been used to project the potential climate change impacts on public health for mycotoxins in wheat, protozoa in drinking water, and *Vibrio parahaemolyticus* in oysters to better understand the range of food and water safety related implications of climate change (49).

Conclusion

The prevalence of foodborne illnesses is likely to increase with climate change. This is attributed to anticipated increases in both the pathogens that already commonly cause foodborne illness and the emerging pathogens, including those that produce mycotoxins and other rare pathogens, which have been found to be present in some imported foods. The treatment of foodborne illness will be complicated by trends in antimicrobial resistance; however, the effect of climate change on foodborne illness is not linear due to a number of modifiable risk factors, and this needs to be the focus of both clinical and public health efforts. Additional research, including those using techniques such as mathematical modelling, can identify new approaches to prevention, early detection and mitigation.

Authors' statement

BAS — Conception, analysis and data interpretation, writing and editing
AF — Conception, writing and editing

Conflict of interest

None.

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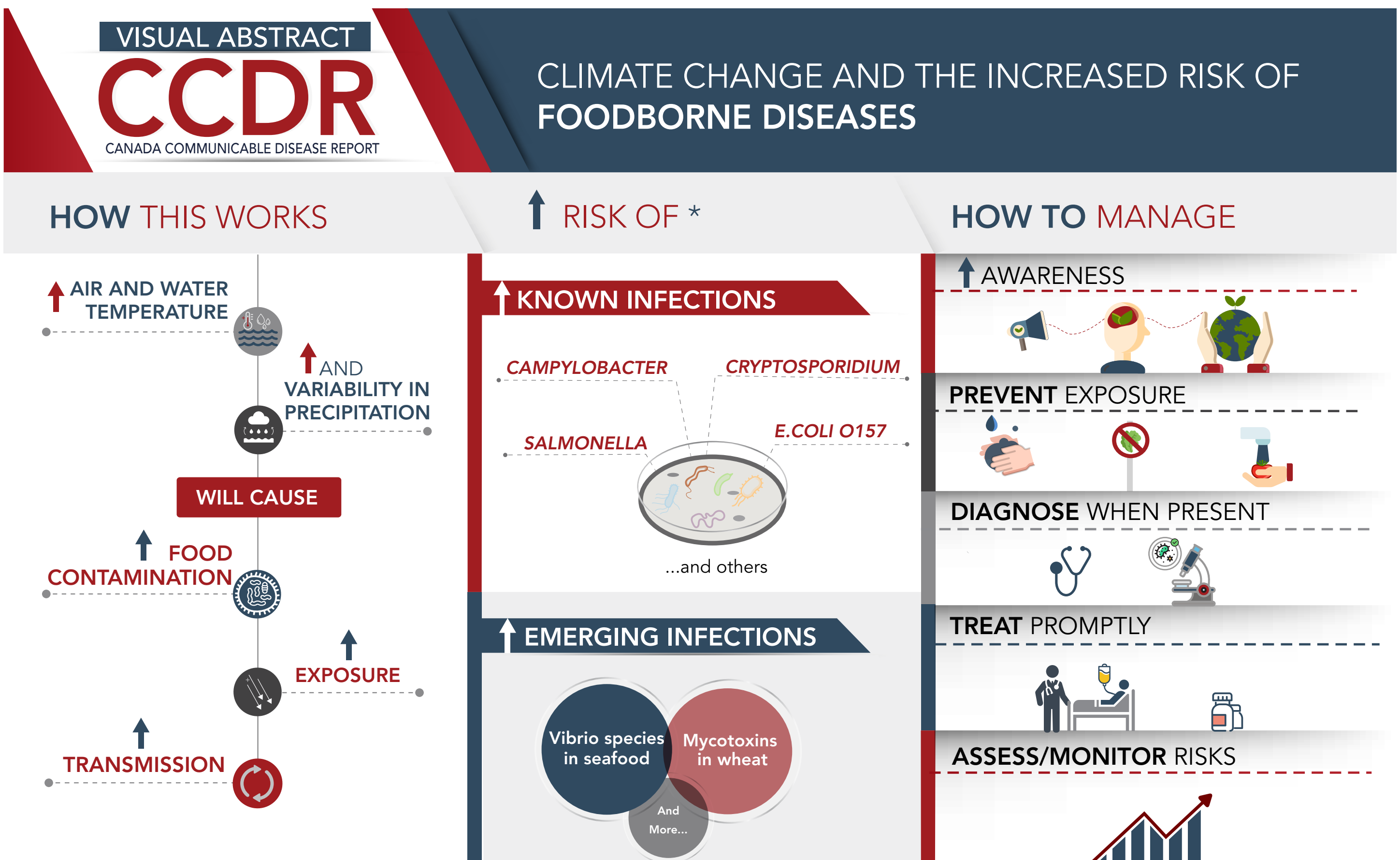

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* *Note: An increase in foodborne illnesses with climate change involve complex systems with many interacting factors*

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