Changing climate

A 'threat multiplier' for foodborne and waterborne infectious diseases and antibiotic resistance

Dr Aliyar Cyrus Fouladkhah of Tennessee State University is an Assistant Professor in Public Health Microbiology. His laboratory explores preventive measures for the spread of infectious diseases, antibiotic resistance, and food security in the landscape of changing climate. His research aims to provide better understanding of the ecology, epidemiology and effectiveness of control measures of enteric and environmental pathogens at planktonic and biofilm stages, including several foodborne and waterborne bacteria. His work contributes to reducing the current burden of premature morbidity and mortality associated with infectious diseases and antibiotic resistance.

According to the U.S. Centers for Disease Control and Prevention, achieving safe and healthier foods is one of the top ten achievements of 20th century public health. Despite the marked progress, considerable challenges remain to further assure the safety and security of food and water supplies, with one in six adults in the United States experiencing illness from foodborne pathogens in a typical year. Foodborne diseases cause an estimated 420,000 deaths worldwide each year. Furthermore, climate change is expected to enhance the spread of infectious diseases since changes in environmental temperatures appreciably augment the multiplication of bacterial pathogens.

The research group of Dr Aliyar Fouladkhah at Tennessee State University addresses these emerging and re-emerging challenges. His laboratory utilises new technologies, such as pressure-based pasteurisation of food products with novel and traditional bacteriocin and bactericidal compounds to mitigate the risk of foodborne infectious diseases. His programme is additionally active in studying biofilm formation capability of pathogens of public health concerns on various biotic and abiotic environments.

Dr Fouladkhah's research embraces an integrated approach for further prevention of infections caused by pathogenic bacteria in food and water supplies. His team works closely with diverse audiences for the dissemination of his finding and to provide food and water safety regulatory and technical assistance to national and international stakeholders. In addition to his research and outreach in Nashville, in recent years he has disseminated his work as an instructor of public health workshops in Guatemala, Dominican Republic, and South Africa.

THE ROLE OF CLIMATE CHANGE

Microbial pathogens have an incredible ability to evolve and move towards '*fitness*' in response to changes in their environment. Climate change will have pronounced effects on the proliferation, survival, and spread of microbial pathogens, and thus on the prevalence of foodborne and waterborne diseases. More than 200 diseases, known to be transmitted through contaminated food and water, may provide examples of the effects of climate change on the magnitude of infectious diseases. One example of this is salmonellosis, an infection caused by nontyphoidal *Salmonella enterica* serovars, which is currently responsible for over one million cases of foodborne illness in the United States in a typical year.

Recent estimates indicate that an increase of just 1°C (above 5°C) could lead to a 5 to 10% increase in the number of cases of salmonellosis. That is equivalent to an additional 50,000 to 100,000 episodes of illnesses due to salmonellosis every year in the U.S. Without significant intervention, the global temperature is projected to rise by as much as 4.8°C by the end of the 21st century.

CLIMATE CHANGE AND ANTIBIOTIC RESISTANCE

In addition to overall infection rate, climate change can also influence the spread of antibiotic resistance. The increasing number of infections requires additional treatments with antibiotics in healthcare facilities and animal husbandry, thus increasing the risk of further antibiotic resistance spread. Currently, treatment of bacterial infections heavily relies on antibiotics, but efficacy of these treatments is diminishing, with resistance in many of the common bacterial pathogens now categorised as a public health threat.

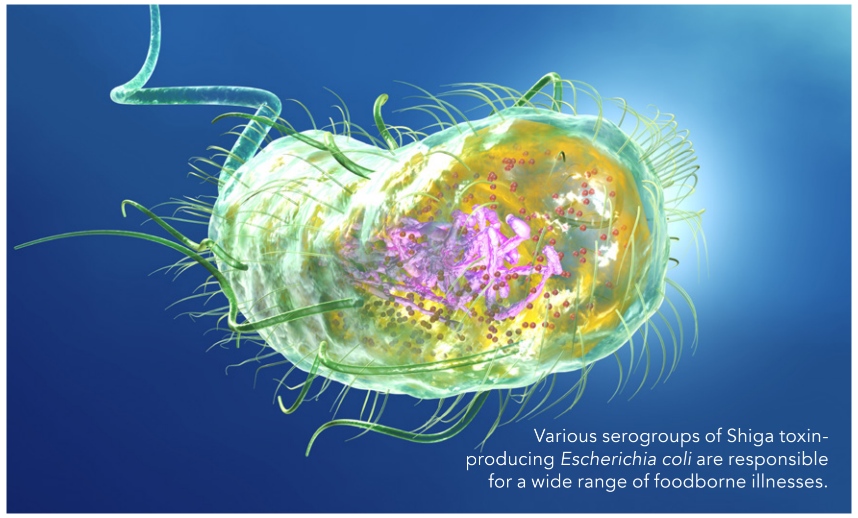
Dr Fouladkhah comments that, although there is a focus on identifying new classes of antibiotics, this strategy alone is not sufficient to alleviate the public health challenge of antibiotic resistance. He emphasises that a holistic 'one health' approach should be embraced, which includes limiting the use of current antibiotics to those individuals with dire need for antibiotic therapies and incorporating evidence-based stewardship programmes such as susceptibility testing and watchful waiting in hospitals. This also requires eliminating or minimising the prophylactic and sub-therapeutic use of antibiotics in animal husbandry as the spread of antibiotic resistance in animal populations could be very closely associated with human health complications. Additionally, continuing the search for new antibiotics and antimicrobials, implementing microbial hurdle validation studies in processing and manufacturing, and multiagency efforts to mitigate climate change could assure the control of antibiotics resistance.

Ultimately, Dr Fouladkhah states that the "climate change-induced antibiotic resistance threat will affect citizens of countries with suboptimal public heath infrastructure the most, those who have contributed least to current changes of climate, and will be a pronounced public health challenge for everyone, particularly vulnerable populations – the very young, elderly, immunocompromised, and pregnant women."

BIOFILM FORMATION IN SURFACE WATER

Dr Fouladkhah highlights that the safety of water supplies is also linked to climate change, as climate change-induced extreme weather events impact the spread and proliferation of pathogens, and the presence of pathogenic bacteria in water systems can cause an array of infectious diseases in humans.

Since temperature and humidity can influence the persistence of bacteria, a recent study by Dr Fouladkhah's research group investigated the presence of three bacteria of public health concern in waters of different temperatures (5, 25 and 37°C) and on stainless steel and rubber surfaces. They found that the bacteria included in the study could survive in surface water and form complex biofilms (a collection of microbes which stick to each other and the surface they live on) on abiotic surfaces, detectable for up to 28 days. These results suggest that the occurrence of contamination in water supplies can lead to prolonged survival of these pathogens, even in environments where they have reduced access to nutrients. This could be an important contamination route to raw agricultural commodities, particularly those that are consumed without any additional treatments. This is also important to consider in the case of our changing climate, as climate change-induced events are expected to further accelerate the spread of waterborne infections.



Various serogroups of Shiga toxin-producing *Escherichia coli* are responsible for a wide range of foodborne illnesses.

Climate change is one of the most significant public health challenges of our time and threatens the safety of our food and water supplies.

STUDYING SHIGA TOXIN-PRODUCING *ESCHERICHIA COLI*

Public health guidelines around the world recommend an increase in the consumption of fruits and vegetables. However, contamination of these fresh produce is almost unavoidable given their growing and processing conditions. Contamination of these crops is particularly important since many of them do not receive any additional processing or treatment before consumption.

Various serogroups of *Escherichia coli* (*E. coli*) are among the top causes of foodborne illnesses, in particular O157 *Shiga toxin-producing E. coli* (STEC) and non-O157 *Shiga toxin-producing E. coli* (nSTEC). The majority of illnesses relating to these serogroups are derived from foodborne infections.

Pressure-based pasteurisation, the application of elevated high pressure to packaged food for around three minutes, can be utilised for keeping food safe, while protecting its sensory and nutritional composition. It is often used, for example, to preserve meat products, fluid milk, fruit juices, and ready-to-eat commodities.

Dr Fouladkhah and his research group members have shown that both STEC and nSTEC bacteria are reduced after high-pressure treatments. Interestingly, they found that the reduction in bacteria could be affected when they allowed the bacteria to habituate to their environment prior to receiving pressure treatments. This finding suggests that using different laboratory approaches may under or overestimate the effectiveness of a treatment, and thus successful and generalisable microbiological validation

Listeria monocytogenes has one of the highest mortality rates associated with a foodborne pathogen.

Foodborne diseases cause an estimated 420,000 deaths worldwide each year.

experiments, such as their study, should be performed considering realistic intrinsic and extrinsic factors of a product and the habituation of the pathogen to assure validating conditions are closely replicating the actual processing conditions of a product.

PRESSURE-TREATMENT OF *LISTERIA MONOCYTOGENES*

In addition to *Shiga toxin-producing E. coli*, pressure-based pasteurisation is also efficacious for pasteurisation and decontamination of other foodborne pathogens, such as *Listeria monocytogenes*. Although relatively rare in occurrence, this bacterium is responsible for one of the highest mortality rates associated with any foodborne pathogen, causing over 200 deaths per year in the United States. Pregnant women, the elderly, the very young and those with existing medical conditions are particularly susceptible to infections with this ubiquitous pathogen.

Dr Fouladkhah's research group aimed to investigate the impact of mild heat and high-pressure pasteurisation for elimination of *Listeria monocytogenes*. The team found that exposing the bacteria to increased pressure did result in a >99% reduction of the pathogens. The pressure-based treatment showed additional decontamination efficacy when coupled with mild heat (40°C). The results of this study provide an alternative to heat-based pasteurisation at high levels for elimination and reducing the risk from *Listeria monocytogenes*. The study thus suggests that pressure-based pasteurisation could be incorporated into food safety management systems as well as in risk assessments related to food processing.

BEST PRACTICES FOR PREVENTION OF INFECTION WITH PATHOGENIC *CRONOBACTER*

It is not just fruits and vegetables, or packaged foods that are at risk of propagating bacteria. *Cronobacter sakazakii* (*C. sakazakii*) is a bacterium which thrives in dry environments, such as powdered infant formula. Although it could cause disease in all age groups, infection is more concerning if it occurs in premature infants or those under two months of age. The research group's recent publication suggests interventions which could be used during and after infant formula manufacturing could minimise the risk of contamination with *C. sakazakii*. These measures include regular testing for microbiological contaminants during processing and washing and sanitising hands, abiotic surfaces, and equipment during formulation and preparation of formula in manufacturing venues, healthcare facilities, and domestic environments. More specifically, the use of validated antimicrobial agents may be appropriate for sanitisation of abiotic surfaces that might be in contact with the product. However, some sanitisers may not fully remove mature biofilms from surfaces, therefore the adoption of these products in a commercial setting must be carefully considered after consulting well-designed validation studies.

BIOACTIVE FOOD COMPOUND EFFECTS ON SALMONELLOSIS

In addition to the use of food processing methods to reduce salmonellosis, there is increasing evidence emerging in the scientific literature that bioactive dietary components may also help prevent infections or manage symptoms of salmonellosis. Interactions of these components (e.g. vitamins, minerals, amino acids, probiotics, and fatty acids) with host interfaces such as bile, gut mucosa, gut immunity, and gut microbiota, are proposed to have a variety of beneficial functions for the prevention and mitigation of foodborne infections. Whilst there are some challenges for conducting pre-clinical and clinical trials to test the effectiveness of these compounds in humans, such as ethical and feasibility considerations, Dr Fouladkhah's team highlights an array of associations between bioactive food compounds that could play an important role in reducing the public health burden of salmonellosis.

CONCLUSION

Climate change is one of the most significant public health challenges of the 21st century and threatens the safety of our food and water systems. Without coordinated global measures to control climate change, the level of greenhouse gas emissions will continue to increase. There is an urgent need to further understand the risks to food and water supplies so that vulnerability assessments can be done, and climate mitigation, adaptation, and resilience programmes can be developed to combat this threat to food and water safety and security.

Dr Fouladkhah's research increases knowledge of preventive measures for the spread of foodborne and waterborne infectious diseases and antibiotic resistance in the landscape of climate change. His outreach and technical assistance are complemented by new findings arising from laboratory studies and create a translational approach for reducing infectious diseases, in addition to highlighting the need for control and prevention measures at population and commercial levels.

Behind the Research

Dr Aliyar Fouladkhah

E: afouladk@tnstate.edu **T:** +1 970 690 7392 **W:** https://publichealthmicrobiology.education

Research Objectives

Prof Fouladkhah investigates preventive measures for foodborne and waterborne infectious diseases and antibiotic resistance in the landscape of changing climate.

Detail

Aliyar Cyrus Fouladkhah
Public Health Microbiology Laboratory
Tennessee State University
Nashville, TN 37209
USA

Bio

Alumnus of Colorado State and Yale University, Dr Fouladkhah is the faculty director of Public Health Microbiology laboratory. His extramurally funded programme has provided education opportunities for undergraduate, MS, PhD, and post-doctoral students/fellows. He had served as exam writer/reviewer for both Certified in Public Health (CPH) and Certified Food Scientist (CFS) national examinations.

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Collaborators

- Shannon Coleman, Food Science and Human Nutrition, Iowa State University
- Wenqing Xu, Cooperative Extension Program, Louisiana State University
- Janey Camp, School of Engineering, Vanderbilt University
- Brian Thompson, School of Public Health, Yale University
- Kushal Patel, School of Public Health, Tennessee State University

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Personal Response

In what ways can government and regulatory agencies further help to reduce the spread of infectious diseases derived from food and waterborne pathogens?

" The U.S. Centers for Disease Control and Prevention estimates, sadly, more than 3,000 Americans die every year because of food-related microbial diseases. Rather than reacting to outbreaks, additional evidence-based and preventive regulations such as Hazard Analysis Critical Control Point regulation and the recent U.S. Food Safety Modernization Act legislation could further assure safety of our food and water supplies. National and international climate change mitigation, resilience, and adoption programmes could additionally safeguard the consumers of the 21st century against natural and anthropogenic microbial diseases associated with food and water supplies in the landscape of climate change. "