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Significance of Climate Change in Food Safety and Hygiene

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Abstract

Context: Climate change has a profound impact on food safety and poses a significant threat to public health. The effects of climate change are inevitable due to alterations in rainfall patterns, increasing weather events, and the average annual temperature. With the progress of climate change, extreme weather events and natural calamities will become more common.
Evidence Acquisition: We searched electronic databases, including Scopus, PubMed, and ScienceDirect, for papers concerning climate change and food safety or hygiene.
Results: Changes in weather patterns, along with an increase in the earth's temperature, can increase food infections, poisonings, antibiotic consumption, and microbial resistance. Lack of healthy agricultural water causes changes in pests, more use of agricultural pesticides, and chemical pollution.
Conclusions: Floods and rainfall changes bring about fungal growth of agricultural products and bacterial growth and accumulation of toxins in seafood. This study reviewed climate changes in the past and present food safety and warned of emerging risks.

Keywords: Food, Global Warming, Food Safety, Climate Change

1. Context

Climate change has a profound impact on food safety and poses a significant threat to public health. The effects of climate change are inevitable due to alterations in rainfall patterns, increasing weather events, and the average annual temperature (1). With the progress of climate change, extreme weather events and natural calamities will become more common (2). During the last 2 centuries, human activities have significantly affected greenhouse gas emissions, with organochlorine emissions increasing by 30%, from 280 ppm (before industrialization) to 387 ppm now (3).

Climate change affects the durability and incidence of microorganisms, harmful algae, fungi, molds, patterns of food-related illnesses, and the risk of toxic contamination. In addition, changes in animal and plant pests lead to an increase in chemical pollution caused by the use of pesticides and antibiotics (1).

Due to climate change during the 21st century, temperatures are expected to increase at high latitudes, more in dry areas than in wet areas. These changes reduce food quality and safety and cause land destruction, decreased biodiversity, floods, climate contamination, and alteration in aquatic ecosystems and algal blooms (4). The global expansion of algal blooms contaminates water-purifying organisms (5).

The distribution of microorganisms in ocean water has significantly changed; for example, the construction of dams and water supply projects have caused the spread of schistosomiasis caused by snails in Africa and the Middle East. Deforestation and ground-level changes have also provided the basis for the newfound and recurrence of infectious diseases (6).

Some of the important environmental effects of climate change include rising temperatures, changes in the water cycle, and the recurrence of extreme weather events, such as heat waves, droughts, and floods. Drought reduces agricultural productivity, along with reducing access to clean water (7). Contaminated water in agriculture is associated with the prevalence of foodborne illnesses (5). The prevalence of zoonotic diseases (transmitted from animals to humans) is increasing in hot weather and during periods of drought, which will significantly impact public health (8).

According to the studies, climate change continues, especially in developing countries that have less adaptive capacity, and leads to a decrease in crop yields, especially in hot and tropical regions (9). For example, mycotoxins are often more common in hot and humid areas. It is estimated that 25% of countries' annual agricultural production is contaminated with fungal toxins (10).

Based on the literature, climate change poses a significant threat to the safety of food and feed, endangering the health of humans, plants, and animals. It is also recognized as a potential risk in the development of emerging diseases (11). The COVID-19 pandemic is a clear example of food contamination that led to an unprecedented epidemic in the world (12).

Therefore, the purpose of this research was to investigate the effects of climate change and its consequences on the safety and hygiene of food from the past to the present, as well as to observe the changes in diseases caused by it.

2. Evidence Acquisition

This review study aimed to examine the effects of climate change on food safety and hygiene indicators. The analysis was based on a comprehensive review of existing articles published between 2004 and 2023. The review included various databases, such as ScienceDirect, Scientific Information Database (SID), Elsevier, PubMed, and Scopus; in addition, the Google Scholar search engine was used to find relevant studies. A total of 570 articles were found after removing duplicates. The inclusion criteria for selecting relevant articles were based on their relation to the topic and inclusion of specific research keywords (global warming, foodborne disease, sea pollution, food contamination, and soil contamination). The current review included studies that investigate the impact of climate change on foodborne microorganisms and chemical toxins in foods.

3. Results

A total of 23 articles were investigated in detail. The summary of the results of the studies is presented in Table 1. In the following, we discussed more details.

3.1. Impact on Food-Related Pathogens

A study in Canada and Australia showed that generally, the number of salmonellosis cases increased by 5% to 10% with each degree of weekly temperature rise (13). A potential increase of 1°C above the average weekly maximum temperature may cause 7% more salmonellosis in cities such as Adelaide. In Ireland, 2% and 3% increases in salmonellosis and campylobacteriosis, respectively, are expected in the future due to climate change (16).

A study of campylobacteriosis in 18 countries showed that most countries in Europe showed peak infection in early spring, but this pattern is not observed in all countries. Inside countries, there are changes in geographic patterns compared to seasonal patterns; however, the role of short-term temperature increase in the increase of human campylobacteriosis is unknown (15). Notwithstanding the relationship between increasing temperature and campylobacteriosis, most researchers have seen this relationship in spring (5 and 10 - 15°C) (17).

A new study shows that the increase and decrease of cholera patients in different seasons in Bangladesh can be attributed to changes in temperature and rainfall. In particular, the first and second peaks of the disease are in low and high rainfall seasons, respectively. While the temperature is low, a reduction in infection rates occurred in winter (18).

There is evidence that infectious diseases, especially diseases of cold-blooded arthropods (such as mosquitoes and mites), are affected by climate change. Moreover, there is strong evidence that this is related to increased epidemic diarrhea, such as cholera, Rift Valley fever (transmission of food by consumption of unpasteurized milk), and shigellosis (20).

Climate change, such as heavy rainfall, affects the outbreak of food-related protozoan diseases (such as cryptosporidiosis and giardiasis). As the first intermediate host, all trematodes use mollusks (generally snails); the production of cercaria in snails is one of the basic stages of the parasite transmission cycle that is affected by temperature. In the living temperature of the parasite and the host, increasing the temperature causes a rise in cercaria output (21).

Barati et al. observed similar results in a review study in 2017. According to their study, parasitic protozoa are more affected by climate change and temporal and spatial patterns than parasites (such as worms). Among worm diseases, climate change affects the range of trematode ones (like fascioliasis) because there is an intermediate host (snails) in their life cycle (22).

Research shows the risk of zoonotic and non-zoonotic diseases in animals whose distribution is highly volatile under the affection of climate change (23).

Table 1. The Summary of the Results of Studies

Authors and Year	Subject	Summary of the Results
Impact on Food-Related Microorganisms		
(Naicker, 2011; Zhang, et al., 2010) (8, 13)	Impact of temperature change on salmonellosis	Temperature rise associated with increased disease
(Skelly & Weinstein, 2004) (14)	Impact of temperature change on salmonellosis	An increase in temperature is effective in the transmittance of Salmonella
(Kovats et al., 2004) (15)	Impact of temperature change on campylobacteriosis	Most countries in Europe show peak infection in early spring, but this pattern is not observed in all countries.
(Cullen, 2009) (16)	Impact of temperature change on campylobacteriosis	A 3% increase in campylobacteriosis is expected in Ireland.
(Lopman et al., 2009) (17)	Impact of temperature change on campylobacteriosis	The relationship between temperature rise and campylobacteriosis was positive.
(Hashizume et al., 2010) (18)	Impact of temperature change on *Vibrio* infection	Changes in the number of cholera cases in Bangladesh in different seasons can be attributed to changes in temperature and rainfall.
(Martinez-Urtaza et al., 2010) (19)	Impact of temperature change on *Vibrio* infection	The seasonal spread of *V. vulnificus* and *V. parahaemolyticus* diseases associated with oysters harvested from April to November corresponded to the warmer water temperatures.
(Woolhouse and Gowtage-Sequeria, 2005) (20)	The effects of climate change on infectious diseases	Climate change is associated with increased epidemic diarrhea, such as cholera, Rift Valley fever, and shigellosis
(Poulin & Mouritsen, 2006) (21)	The effects of climate change on food-related protozoan diseases	A rise in temperature is associated with increased protozoan diseases, such as cryptosporidiosis and giardiasis.
(Barati et al., 2017) (22)	The effects of climate change on food-related protozoan diseases	Parasitic protozoa are more affected by climate change and temporal and spatial patterns than other parasites.
(Easterling et al., 2007) (23)	The effects of climate change on zoonotic and non-zoonotic diseases	Distribution is highly volatile under the influence of climate change.
(Robens & Cardwell, 2003; Ministry of Jihad-e-Agriculture I.R., 2008; Cotty, 2007) (24)	The impact on fungal diseases	Climate change can cause further contamination of agricultural products with fungi and their toxins.
(EC, 2009) (25)	Climate change and its impact on animals' food	Affects the lives of animals, leading to injuries such as parasites, eating disorders, heat stroke, or dehydration.
(IPCC, 2007) (26)	Climate change and its impact on animals' food	Exposure to cold, heat, humidity, etc, makes cows susceptible to complex bacterial syndromes.
(FAO, 2008) (27)	Climate change and its impact on animals' food	Countries with temperate climates will be very vulnerable to invading carrier-linked viral diseases.
Climate Change and Its Impact on Food-Related Chemical Contamination		
(FAO, 2008) (28)	Climate change and its impact on animals and aquatic food	The spread of animal diseases due to climate change can increase the use of medicine for them.
(Zo et al., 2008) (29)	Climate change and its impact on animals and aquatic food	Human activities have released significant environmental chemical pollutants.
(Baines et al., 2006) (30)	Climate change and its impact on animals and aquatic food	Many marine organisms tend to biologically accumulate and store toxic metals in the environment.
(Booth & Zeller, 2005) (31)	Climate change and its impact on animals and aquatic food	Raising the temperature of water can facilitate the methylation of mercury and its subsequent absorption by fish and mammals.
(Chen and McCarl , 2001) (32)	Impact on soil, agriculture, and pesticide residues in plants	Warming, increasing rainfall, and related diseases will increase the consumption and cost of pesticides for crops.
(Rosenzweig et al., 2005) (33)	Impact on soil, agriculture, and pesticide residues in plants	It was observed in Brazil that excessive rains led to the development of soybean rust.
(Dittmar et al., 2007) (34)	Impact on soil, agriculture, and pesticide residues in plants	The concentration of arsenic in rice is gradually increasing due to the irrigation of fields with contaminated water.
(Umlauf et al., 2005) (35)	Impact on soil, agriculture, and pesticide residues in plants	Very high levels of PCDD/FS were present in riverine pastures and floodplain pastures.

Abbreviation: PCDD/FS, benzo-p-dioxin, and di-benzo furans.

3.2. Impact on Fungal Diseases

In South America, the increase in the contamination of agricultural products with aflatoxin has made them unusable due to the heat (24).

The effect of climate variation on adapted trees to semi-arid climates, such as pistachios, is unclear. In periods with temperatures more than the mean and more rain in Kerman (Iran), an increase in the rate of spoilage and aflatoxin contamination in nuts has been recorded (36).

3.3. Impact on Animals and Aquatic Food

These changes can have effects on the susceptible animals to disease, which in turn affects their lives, leading to injuries such as parasitic diseases (eg, nematode and *Taenia*), eating disorders, heat stroke, or dehydration. Climate change is particularly important in diseases caused by carriers, rodents, and animal parasites. The spread of animal illnesses due to weather changes can increase the use of medicine, which leads to an increase in undesirable amounts of veterinary drugs in foods prepared from animals (27). Due to the susceptibility of carriers and hosts to weather, including changes in rainfall and temperature, the prevalence of many common diseases between humans and animals and the vector also changes seriously in different seasons (37).

One study has shown that aquatic animals are very sensitive to changes in aqueous conditions because their metabolism is affected by temperature, salinity, oxygen levels, and the ecosystem. Fish respond directly to climate fluctuations and environmental changes (predators, species interactions, and disease) (26).

In recent decades, human activities have released significant environmental chemical pollutants, including polycyclic aromatic hydrocarbons, heavy metals, and manufactured chemicals. These materials, such as polychlorinated biphenyls (PCBs), dioxin, and tributyltin (TBT), are by-products of industries and agriculture (30). Changes in temperature and rainfall can intensify water contaminants, as well as sediments, nutrients, microorganisms, heavy metals, and salinity (38).

Many marine organisms that are inclined biologically store environmental toxic metals, which they excrete or detoxify through their eggs and feces. Temperature, salinity, and lack of oxygen have an impact on living organisms and, thus, the safety of seafood. In a 2005 study, Booth and Zeller reported that increasing water temperatures facilitated the process of Hg methylation. Additionally, their study found that with each degree rise in temperature, there was a corresponding increase in the uptake of methylmercury by aquatic organisms and mammals by approximately 3% - 5% (30, 31). Furthermore, the accumulation of cadmium by *Mytilus* oysters was higher at 12°C compared to 2°C, and the uptake of lead increased at 26°C compared to 6°C (31).

The effect of increasing salinity and toxicity of 2 insecticides (Scourage and chlorothalonil) on *Palaemonetes pugio* shrimp showed that chlorothalonil's toxicity increases with rising salinity. It was also reported that rising temperatures are a major factor in the distribution and toxicity of organochlorine compounds (11).

Climate change can also provide suitable aquatic environments for producing harmful algal blooms (HABs). Studies have shown that Ciguatera fish poisoning (CFP) is the most prevalent form of seafood poisoning, with some studies showing a compelling relationship between climate, HABs, and the prevalence of CFP in the tropics (39).

3.4. Impact on Soil, Agriculture, and Pesticide Residues in Plants

Climate change in adverse environmental conditions with increasing crop pests may lead to the abuse of pesticides. This may lead to increased pollution with pesticide residues in agricultural products. It is predicted that warming, increasing rainfall, and related diseases will increase the consumption and cost of pesticides for crops (32).

Studies have shown that the concentration of arsenic in rice is gradually increasing due to the long-term irrigation of fields with contaminated water (34). After the massive Elbe and Mulde floods in 2002, several researchers conducted surveys to assess flood contamination and identify contamination transmission to the food chain. According to the information obtained, a very large amount of di Benzo-p-dioxin and di-benzo furans (PCDD/FS) was present in riverine pastures and floodplain pastures, which contained evidence of significant PCDD/FS transmission to animal milk (35). Furthermore, following Hurricane Katrina in South America in 2005, sources of chemical pollution, including oil spills, pesticides, 2-4D (an herbicide), some heavy metals, benzidine, etc, were found in flood water and soil (40).

4. Conclusions

Global warming affects the earth's habitats and the functioning of ecosystems. Climate change is caused by changes in the amount of atmospheric carbon dioxide, temperature, and precipitation worldwide, which affects sea level, salinity, soil, and plant and crop diversity. Changes in the water cycle, droughts, and floods can change the geographic distribution of food-borne diseases. An increase in temperature can lead to an increase in the prevalence of bacterial foodborne diseases. The trend of changes in infection and food poisoning with bacteria, parasites, fungi, and viruses is now more visible. Moreover, rising temperatures can lead to increased contamination of agricultural products with fungi and their toxins. This can result in a higher demand for pesticide usage to mitigate fungal growth and reduce crop damage and can lead to higher levels of agrochemical residues in crops and the environment. These variations, including changing risks and increasing their unpredictability, highlight the necessity for enhanced research and monitoring in this field. By observing the process of pathogenic changes, the readiness to deal with the potential risks of emerging diseases increases.

Footnotes

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