Int.J.Curr.Microbiol.App.Sci (2025) *14*(02): 122-135

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 14 Number 2 (2025)**
Journal homepage: http://www.ijcmas.com

Review Article https://doi.org/10.20546/ijcmas.2025.1402.011

The Vital Role of Food Safety in Mitigating Microbial Hazards

Shreya Das, Snehasis Polley and Sayan Bhattacharyya*

Department of Microbiology, AIIH&PH, Kolkata, BN Campus, Kolkata-700106, India

**Corresponding author*

Keywords

Food safety, hand washing, HACCP

Article Info

Received:
15 December 2024
Accepted:
22 January 2025
Available Online:
10 February 2025

A B S T R A C T

Microbial contamination of food can occur through various routes. Contaminated water, improper handling, inadequate cooking temperatures, and cross-contamination are common culprits. Mitigating microbial hazards requires food safety practices like Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), Application of HACCP system in food handling area etc. Hand cleaning, keeping raw and cooked food separate, boiling food to safe temperatures, and correctly transporting and storing food are all part of this. People, facilities, equipment, production materials, and containers should all be maintained clean and sanitary, and time and temperature should be managed, in order to prevent contamination during the product manufacturing process. Major machinery in food facilities must always be cleaned and sanitized in accordance with SOPs (standard operating procedures).Technological advancements are becoming increasingly important for enhancing food safety. Innovative packaging methods can extend the shelf life of products and prevent the growth of microorganisms. Lateral flow immunochromatography (LFI) is a popular food safety detection technique in clinical medical treatment, environmental monitoring, and food safety testing due to its simplicity, speed, specificity, and affordability. Additionally, it is necessary to guarantee the safety of food. Using conventional methods in the detection of pathogenic microorganisms in food has no sufficient performance, however, newly established methods like Nano sensors have resolved this problem by rapid detection of pathogenic strains and the identification of their released toxins in all stages of the food production. Through the application of nanoparticles with antibacterial action, nanotechnology has recently offered a novel method against a variety of multiple drug-resistant pathogens.

Introduction

In most nations, particularly those that are not industrialized, the prevalence of food-borne illnesses still has a negative impact on people's productivity and general health. However, since the 1950s, the focus in the industrialized world has switched from addressing public health issues to issues with chemical toxins, etc., but in recent years, governments and the food industry have once again grown increasingly concerned about food-borne diseases. Food may now be supplied globally thanks to advancements in international transportation, but parasites and other viruses that can taint food can also spread (Untermann, 1998; Northrop-Clewes and Shaw, 2000). Food safety is a critical public health concern, deeply intertwined with the prevention and control of microbial hazards. Microorganisms, including bacteria, viruses, fungi, and parasites, can contaminate food at any stage of the supply chain, from farm to fork, leading to foodborne illnesses. These illnesses can range from mild gastrointestinal upset to severe, life-threatening conditions. Thus, ensuring food safety is paramount in safeguarding public health and well-being. Food-borne illnesses are hardly ever reported in India. Foodborne illnesses are seen as having less significance in developing and underdeveloped nations because of the high frequency of other serious illnesses. Pathogenic microorganisms including bacteria, viruses, and parasites, or their toxins found in food, are the cause of food-borne sickness. There are over 250 identified food-borne illnesses. Ingestion of food containing viable (living) bacteria, such as *Salmonella*, *Listeria*, or pathogenic *E. coli*, can result in various bacterial foodborne infections, which are foodborne illnesses that cause the host to proliferate or multiply. Contrarily, bacterial food intoxication is a foodborne sickness brought on by consuming food that contains preformed bacterial toxins (such as those made by *Clostridium botulinum* and *Staphylococcus aureus*) that are created as a result of bacterial growth in the food. Food toxicoinfection, which happens when bacteria (like *Clostridium perfringens*) found in food are consumed and cause toxins to be produced in the host, is the third form of bacterial food-borne illness in addition to food infection and intoxication (Singh *et al.,* 2011).

Microbial Hazards in Food: A Diverse Threat

Some of the most concerning microbial hazards in food include:

Bacteria

Salmonella, *Escherichia coli* (particularly *E. coli* O157:H7), *Campylobacter*, *Listeria monocytogenes* (via chilled food or water or canned food), and *Staphylococcus aureus* (via stale sweets) can cause a range of illnesses, from vomiting to diarrhea to kidney failure. There are bacteria that can make one sick with their toxins. These toxins can be either heat-stable (like *Staphylococcus* enterotoxins/Enterotoxin A which behaves as a superantigen) or heat-labile (like Botulinum toxins). However, infectious pathogens have a more significant epidemiological function. The intricate kinetics of bacterial inactivation, survival, and growth give them a unique significance as microbial hazards in food (Untermann, 1998).

Viruses

Poliovirus, hepatovirus (hepatitis A), and several gastroenteritis viruses, such as rotavirus, as well as astrovirus and caliciviruses, such as Norwalk and Norwalk-like viruses, are among the virus species for which foods can act as vectors (Adams and Moss, 1995). These agents are found in humans. In essence, the feco-oral pathway is how it spreads. In this case, foods may act as vectors. Man-made contamination of the food can occur directly or indirectly through tainted water. Hepatitis A and gastroenteritis outbreaks have been linked to the ingestion of raw shrimp or oysters. Norovirus, rotavirus, and hepatitis A virus can contaminate food through fecal-oral transmission, often due to poor hygiene practices (Untermann, 1998).

Fungi

Molds can produce toxins, such as aflatoxins, patulin and ochratoxins, which can contaminate crops like rice, apple, peanuts and different grains, posing a risk of liver cancer and other health problems. Molds that produce mycotoxins are among the fungi that must be noted in relation to foodborne illnesses. Although the microorganisms themselves are not harmful to people when ingested, their mycotoxins must be regarded as such. Molds in food or raw materials can produce mycotoxins that may be consumed by man. They may, however, also be consumed by animals through feed and then eliminated, for instance, as milk. For instance, cattle consume aflatoxin B, which is then transferred into milk as aflatoxin M. Mycotoxins are tiny molecular compounds that are extremely resistant to heating processes and cannot be eliminated by them. extrinsic impacts of bacteria. As a result, presently utilized (Untermann, 1998).

Parasites

According to the World Health Organization (WHO), parasite infections rank higher than cancer as the leading cause of death worldwide and are one of the six most dangerous infectious illnesses that affect humans. Eating tainted undercooked beef, pork, fish, or other meat products, walking barefoot on polluted soil, getting bitten by a fly or mosquito, consuming dirty raw fruits and vegetables, or drinking contaminated water can all result in parasite infection. Traveling to tropical and/or less developed nations increases the chance of catching parasites, and the growing number of immigrants from infected regions also raises the risk.

Entamoeba histolytica, Giardia lamblia, *Toxoplasma gondii*, *Cryptosporidium*, and various helminths can contaminate food and water, and cause parasitic foodborne infections (Northrop-Clewes and Shaw, 2000). There is also substantial risk of developing Vitamin B12 deficiency after eating fish harbouring the fish tapeworm *Diphyllobothrium latum*.

Cross contamination during food handling

The findings of a study conducted by J. Kennedy A. Nolan S. et.al, demonstrated that failing to properly wash contaminated hands, knives, and chopping boards both before and during the meal preparation process predicts the spread of germs throughout the kitchen and onto cooked meals. There was a strong correlation between the usage of chopping boards contaminated with raw chicken and used to prepare raw salad veggies and the presence of *C. jejuni* in the hot chicken salad. The prevalence of campylobacter in hot chicken salad samples was linked to the presence of *C. jejuni* on participants' hands during meal preparation. The presence of both E. coli and *C. jejuni* on prepared food samples was statistically associated with the lack of complete washing of infected hands and utensils.

The prevalence of *E. coli* on chopping boards during food preparation has been significantly linked with the failure to properly clean blades and chopping boards that had come into touch with raw beef and raw poultry. The results also indicate that taps are a significant source of cross-contamination because hands act as a mediator between the cooked food and the taps. It was shown that the amount of microbial contamination on hands increased while handling meat repeatedly.

Likewise, additional research has demonstrated that a lack of cleanliness during the food preparation process is linked to the spread of bacteria and, crucially, its existence after preparing food that is ready to consume.

Therefore, it has been proposed that the effectiveness of hygiene practices in the home is largely dependent on how and when these practices are applied, and that they should be applied for a specific purpose rather than as part of a routine cleaning process because of how easily and quickly hands can become re-contaminated (Kennedy *et al.,* 2011).

Effect of temperature on microbial growth

The extrinsic and internal environments of food have a significant impact on the shelf life of both fresh and processed food materials. One external factor that influences microbial growth is temperature. Considering preferences for temperature.

The shelf life of both fresh and processed food components is greatly influenced by the interior and external surroundings of food. They fall into one of four categories:

Psychrophiles: Grow well below 5°C, and 12–15°C is the ideal temperature range for them.

Psychrotrophs: These MOs thrive at temperatures between 20 and 30 degrees Celsius, but they may even develop much below that. Among the genera of bacteria There are known psychrotrophic species and strains of *Alcaligenes, Shewanella, Brochothrix, Corynebacterium, Flavobacterium, Lactobacillus, Micrococcus, Pseudomonas, Psychobacter, Enterococcus,* and *Listeria*. The most prevalent psychrotrophs linked to food are *Pseudomonas, Enterococcus,* and *Listeria*. Meats, fish, poultry, eggs, and other items kept in a refrigerator are all spoiled by them. Certain Aspergillus, Cladosporium, and Thamnidium mold strains are psychotrophs and have been linked to eggs, beef sides, and fruits kept in a refrigerator.

Mesophiles: Grow well in temperatures between 20 and 450°C, with 30-400°C showing the best growth. Notably, yeasts and the bacteria En. faecalis thrive in both psychotropic and mesophilic ranges, or temperatures 0-300C or more, but typically not in the thermophilic range.

Thermophiles: 450°C is ideal for growth, with 55–65°C being the ideal range. The genera *Bacillus* and *Clostridium* include the majority of thermophilic bacterial species and strains that are significant in food. Molds may often develop in a variety of temperature ranges.

Many bacteria not only cause food to deteriorate but can also pose a health risk to humans by causing food poisoning if consumed (Charpe *et al.,* 2019).

Most of the Bacteria may double in number in as little as 20 minutes and grow most quickly in temperatures between 40 and 140 degrees Fahrenheit. This temperature range is frequently referred to as the "Danger Zone" (https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/danger-zone-40f-140f#:~:text= public%20health%20organization.-,%22Danger%2 0Zone%22%20 (40%C2%B0F% 20%2D%20140% C2%B0F,levels%20 that%20can %20cause%20illness).

Food safety in street food

Concern over food security and health has led to a global increase in interest in the significance of street food (Omemu and Aderoju, 2008). Street food is defined as foods and drinks that are made and sold by vendors on public spaces such as streets and festival grounds, and that are quickly devoured by customers. These dishes are cheaper than the cuisine served at restaurants and are substitutes to cooked meals. The main reasons why street food is criticized and viewed as a health risk are that the locations where it is prepared and sold are exposed to dirt and contamination, and that the vendors' methods, attitudes, and hygiene during food preparation and storage are inadequate (https://www.j-humansciences.com/ojs/index.php/IJHS/article/view/3925).

The quality of the raw materials used to manufacture foods for sale has an impact on the microbiological safety of street food. Microbes can contaminate food at any stage of the production process, including processing, transportation, storage, display, preparation, and serving for consumption. Poor hygiene, a lack of drinkable water, poor infrastructure, food storage at temperatures that encourage the growth of microorganisms like *S. aureus* and *B. cereus*, contact with household and other animals, such as rats and insects, and air pollution are the main issues.

The microbial contamination of food is more important in lower-income countries because foodborne illnesses are known to cause 2.2 million fatalities there each year, with 1.9 million of those deaths being in children.

The Enterobacteriaceae family's *Salmonella*, *Shigella*, and *Escherichia* genera, along with species like *Staphylococcus aureus*, *Clostridium perfringens*, *Listeria monocytogenes*, and *Campylobacter jejuni*, are the primary bacterial pathogens responsible for foodborne illnesses (Andrade *et al.,* 2023).

Role of probiotics & fermentation on microbial food safety

Governments, industries, and consumers place a high priority on the safety and quality of foods, whether they come from plants or animals. It is commonly known that pathogens, including Salmonella, *Escherichia coli*, Listeria, and Campylobacter, can spread throughout the food chain and cause disease in humans. They can contaminate food and grow in the right environment. Food-borne pathogen-related sickness is currently one of the most pervasive public health issues worldwide (Mor-Mur & Yuste, 2010). Finding ways to stop the spread of dangerous bacteria in the food chain is therefore necessary. Food safety and consumer health may be improved by using beneficial bacteria, primarily lactic acid bacteria (LAB) and bifidobacteria, to prevent or lower the occurrence of pathogens. Furthermore, these microbes might have antimicrobial properties against spoiling microbes, which logically shortens a product's shelf life. These bacteria can be employed as probiotic cultures (living microorganisms that, when consumed by farm animals, can aid in improving animal health) or protective cultures (live microorganisms that, when added to food goods, inhibit pathogens and/or prolong the shelf-life). According to scientists, biological preservation is the process of extending the shelf-life of food products and improving their microbiological safety through two distinct methods: i) inoculating the food matrix with target microorganisms, which are defined as protective cultures. This results in the in situ production of inhibitory molecules and/or a competitive effect against pathogen and spoilage bacteria. Bacteriocins like nisin, colicin and pediocin have been found to ensure and enhance food safety by preventing microbial food contamination. Since LAB are found in all fermented foods and have a long history of safe usage, they are the microbial group most frequently utilized as protective cultures (Gaggia *et al.,* 2011).

Food Safety Practices: A Multi-Barrier Approach

Mitigating microbial hazards requires a comprehensive, multi-barrier approach encompassing various food safety practices:

Good Agricultural Practices (GAP)

The US Food and Drug Administration (FDA) first presented the concepts of Good Agricultural Practices

(GAPs) in the Guidance for Industry Guide to Minimise Microbial Food Safety Hazards for Fresh Fruits and Vegetables (FDA, 1998). This publication includes broad recommendations for lowering the possibility of microbial contamination of fresh food for the fresh fruit and vegetable sector. GAPs serve as the cornerstone of the Produce Safety Rule (PSR) under the recently passed Food Safety Modernisation Act (FSMA). GAPs are considered guidelines and are not mandatory. Implementing GAP on farms can minimize contamination of produce and livestock. This includes using clean water for irrigation, proper manure management, and pest control (De *et al.,* 2025).

Good Manufacturing Practices (GMP)

GMPs are rules designed to guarantee safe, effective, and comprehensive methods that guarantee product quality, safety, and standards (PQSS). GMPs must be adhered to for a variety of product testing, manufacturing, handling, storage, and distribution procedures. Safety, Integrity, Purity, Quality, and Composition (SISPQC) criteria should be met by GMPs. Good Manufacturing Practices (GMPs) should be followed and adopted by food manufacturing and production industries to ensure that all products are made in a safe and healthy environment, guaranteeing quality and safety to meet standards and regulations. Food processing facilities must adhere to GMP to prevent contamination during production. This involves maintaining a clean environment, proper equipment sanitation, temperature control, and employee hygiene (Meghwal *et al.,* 2017).

Who should follow GMP?

Every food processor, pharmaceutical producer, food product manufacturer, packager, labeller, distributor, and keeper of a warehouse or storage facility must adhere to GMP and various food safety and standards rules (Meghwal *et al.,* 2017).

Essentials of GMP Quality Control

- The product satisfies requirements.
- Quality Assurance: Systems provide validation, control, and consistency.
- Documentation: Without documentation, the event was either untrue or only a rumour.
- Self-examination and confirmation (Meghwal *et al.,* 2017).

Hazard Analysis and Critical Control Points (HACCP)

To guarantee that food is safe to eat, HACCP is a methodical, logical, and scientific approach for identifying, evaluating, and controlling biological, chemical, and physical hazards during food production, processing, manufacturing, preparation, and use. The HACCP system was first created to help food processors prevent or manage risks, but its use has been growing and changing over time to serve as a foundation for official food control and the establishment of food safety standards for the global food trade. It is intended to reduce serious food safety risks, or risks that might have a negative impact on a person's health after consuming a product. Specific food safety concerns are identified and tracked by the prevention-based HACCP system. It is overtly clear now that implementing the HACCP system into food preparation and manufacturing can improve food safety and reduce the number of food-borne illness cases. Today, the food industry and food control regulatory bodies throughout the world are interested in implementing the HACCP system as a way to reduce or eliminate food-borne risks and regulate food safety. Application of the HACCP principles has been shown to culminate in more effective food-borne illness prevention practices. In order to lower the prevalence of foodborne illness and guarantee a safe food supply for the general population, as well as to encourage and facilitate trade in food products and boost tourism, many nations have incorporated or are in the process of incorporating the HACCP principles into their regulatory frameworks. All food enterprises, regardless of their size, may use HACCP. It can also be used to improve food safety control in impoverished nations and even in households (Pal *et al.,* 2016). It is illustrated in table 2 below.

In order to ensure that a food or drug is safe, has the right identity, purity, and strength, and satisfies quality and purity requirements, GMP or HACCP sets minimum GMP for the procedures to be followed and the facilities or controls to be used for the manufacturing, processing, packing, or holding of a food or drug (Meghwal *et al.,* 2017).

Benefits of HACCP

HACCP focusses on identifying and preventing food contamination by hazards. * HACCP is founded on sound science and technology;

HACCP assigns responsibility for food safety to the food manufacturer or distributor;
HACCP makes it easier for food companies to compete in the global market; and
HACCP lowers trade barriers. Because HACCP keeps records that show how effectively a company complies with food safety regulations over time rather than just on a single day, it enables more effective and efficient government supervision (Pal *et al.,* 2016).

Proper Food Handling and Storage

Food handlers plays a crucial role in preventing foodborne illnesses. This includes washing hands, separating raw and cooked foods, using separate utensils for raw and cooked foods, keeping food covered after cooking to minimize airborne B. cereus infections, cooking food to safe temperatures like 72 ◦C in case of meat (till periosteum of bone), and storing food properly.

Transportation of Raw Material from Collection Point to Food Industry and Finished Products

When being transported, raw ingredients and completed food items need to be adequately stored and safeguarded. The kind of vehicles or containers used may differ depending on the kind of food items and raw ingredients. For instance, a truck should be refrigerated while delivering ice cream, but not when transporting dry goods like cookies or spices. Bulk containers and food conveyances should not contaminate food or packaging, enable efficient separation of food from non-food items when needed during transportation, and be able to efficiently maintain the temperature, humidity, atmosphere, and other conditions required to shield food from dangerous microorganisms (Meghwal *et al.,* 2017).

Food Product Information: Labelling

Later on in the food chain, improper handling of items may result from a lack of product information and/or basic food hygiene awareness. Even in situations when appropriate hygiene control procedures have been implemented earlier in the food chain, such mistreatment can lead to disease or items being unfit for eating. To guarantee that sufficient and easily accessible information is available to handle, store, process, prepare, and display the product in a safe and proper manner, products should be appropriately labelled. For the next person in the food chain to handle, display, store, and use the product safely, pre-packaged food items must be labelled with clear instructions that comply with applicable laws. In addition to aiding in efficient stock rotation, lot or batch identifying numbers are crucial for product recalls and trace backs. To identify the producer and the lot or batch, every food container should have a permanent label (Meghwal *et al.,* 2017).

Sanitation and Hygiene in Food Processing Industry

To prevent contamination during product manufacture, people, facilities, machinery, production materials, and containers should all be kept clean and hygienic.

Hygiene of the handlers

Personnel should be healthy to perform their assigned works. Regular medical examination must be conducted for all production personnel involved with manufacturing of food. People known, or suspected, to be suffering from, or to be a carrier of a disease or illness likely to be transmitted through food, like Enteric fever, should not be allowed to enter any food handling area (Meghwal *et al.,* 2017).

Premises' Hygiene measures

1. All workers and security personnel in the food business should have access to sufficient restrooms where they can keep their personal things and washing facilities should be present there.
2. To prevent contamination, the manufacturing area should be kept far from the staff's restroom, drinking water, and food canteen.
3. Regular collection of waste materials in appropriate containers for transportation to collection locations outside the industrial area is necessary.
4. Equipment, raw materials, packaging, in-process materials, and final products shall not be contaminated by the use of rodenticides, insecticides, fumigating agents, and sanitizing chemicals for the purpose of cleaning and eliminating rodents, insects, fungi, and bacteria (Meghwal *et al.,* 2017).

Hygiene of Equipment and Apparatus

Utensils and equipment should be maintained in a sanitary and clean state. These days, moist cleaning techniques or vacuuming are recommended. In cleaning process compressed air and brushes should be used with care and avoided if possible, as they increase the risk of product contamination. Always SOP (Standard Operating Procedures) must be followed for cleaning and sanitizing of major machines (Meghwal *et al.,* 2017).

Sanitation Standard Operating Procedures (SSOP)

The SSOP should cover general maintenance, a list of cleaning and sanitizing agents, a good pest control system, a proper storage facility for toxic materials, proper sanitation of surfaces that come into contact with food, the handling and storage of clean portable equipment and utensils, and a facility for disposing of waste materials in accordance with food regulations and orders.

Time and Temperature Control

Time and temperature controls include of recording of time and temperature parameter of

Cooking, cooling, processing and storage.

Hand washing technique by WHO

The followings are the six hand washing steps of social hand washing (by the World Health Organization or WHO) which should be followed in series during every hand washing to avoid entry of microbial hazards in foods:-

Rub palm together
Rup dorsum to palm
Rub in between fingers.
Interlock fingers and rub the back of fingers
Rub nail tips
Rub wrists (https://surewash.com/news/cleaning-your-hands-correctly-during-covid-19/).

WHO's five keys for safer food

One in ten individuals become unwell each year as a result of consuming contaminated food. Individual food handlers and consumers have a significant impact in preventing foodborne illnesses, even though food safety is a shared duty. Therefore, in order to provide all consumers globally with a straightforward and practical set of steps to avoid foodborne illnesses, the "five keys to safer food" messages were create d and approved by an independent group of international experts in 2001. These "five keys to safer food" were created to teach all food handlers and customers safe food handling practices-

1. Keep clean.
2. Separate raw and cooked.
3. Cook thoroughly.
4. Keep food at safe temperatures.
5. Use safe water and raw materials (https://www.who.int/activities/promoting-safe-food-handling/five-key-to-safer-food).

The 4 key steaps here are:- Clean, Separate, cook, chill.

Education and Awareness

Food handlers (FHS) can contaminate food through practices associated with a lack of knowledge about the fundamentals of food safety (FS), such as cross-contamination, proper cooking and storage temperatures, and personal hygiene. FHS training on food safety (FS) is a commonly used strategy to improve FSK (Food Safety Knowledge) and is acknowledged as one of the most important interventions in preventing foodborne disease outbreaks (WHO, 2020). Osaili *et al.,* in 2017 discovered in one of the Jordanian research that the FSK (Food Safety Knowledge) means score among FHS was 56.3/90, indicating the need for food safety (FS) education and training programs. According to Osaili *et al.,* (2013), the FHS (Food handlers) must have a "good" FSK (Food Safety Knowledge) level (above 75%) and a "good" practice level in order to safeguard the customers' meals from foodborne illnesses. Educating food handlers and consumers about food safety practices is essential. This includes training on proper hygiene, food preparation techniques, and the importance of temperature control (Alakash *et al.,* 2022)

Food safety laws and regulations

The Food and Drug Act of 1872 and the Adulteration of Food and Drink Act of 1860 have had a significant impact in the majority of countries, demonstrating the importance of "adulteration" in the modern period. Risk management and assessment are part of the FAO and WHO. Food standards are applied significantly in commerce and dispute resolution by the World commerce Organisation (WTO). The WHO has a significant impact on incident management and runs risk communication systems.

Table.1 Microbial food hazards and their health effects
(Bintsis *et al.,* 2017)

Type	Name of microbes	Toxin released	Incubation period	Health effect
Bacteria	*Staphylococcus aureus*	*enterotoxins*	*1-7hr*	Nausea, vomiting, retching, diarrhea, abdominal pain, prostration
	Bacillus cereus	*emetic toxin*	*8–16 h*	Vomiting or diarrhea, depending on whether diarrheic or emetic toxin present; abdominal cramps; nausea
	Clostridium perfringens	*enterotoxins*	*2–36 h*	Abdominal cramps, diarrhea, putrefactive diarrhea (Cl. perfringens), sometimes nausea and vomiting
	Salmonella spp.	-	*6–96 h*	Fever, abdominal cramps, diarrhea, vomiting, headache
	Enterohaemorrhagic E. coli,	-	*1–10 days*	Diarrhea (often bloody), abdominal pain, nausea, vomiting, malaise, fever (uncommon with *E. coli O157:H7)*
	Clostridium botulinum	*neurotoxins*	*2 h to 6 days*	vertigo, double or blurred vision, loss or light reflex, difficulty in swallowing, dry mouth, weakness, respiratory paralysis
	Yersinia enterocolitica	*enterotoxins*	*3–7 days*	Fever, diarrhea, abdominal pain
	Listeria monocytogenes Campylobacter jejuni	---	*Varying periods*	Fever, chills, headache, arthalgia, prostration, malaise, swollen lymph nodes and other specific symptoms of disease in question
	Vibrio cholerae (O1 and non-O1), Vibrio parahaemolyticus	----	*6 h to 5 days*	Watery diarrhoea in *V. cholerae* and bloody diarrhoea in case of *V. parahemolyticus*
Virus	*Norovirus*	----	*12–48 h*	Nausea, vomiting, watery non-bloody diarrhea, dehydration
	Rotavirus, Astrovirus, enteric Adenovirus	------	*3–5 days*	Fever, vomiting, watery non-inflammatory diarrhea
Parasites	*Entamoeda histolytica*	---	*1 to several weeks*	Abdominal pain, diarrhea, constipation, headache, drowsiness, ulcers, variable—often asymptomatic
	Taenia saginata, Taenia solium		*3–6 months*	Nervousness, insomnia, hunger pains, anorexia, weight loss, abdominal pain, sometimes gastroenteritis
	Trichinella spiralis	----	*4–28 days*	Gastroenteritis, fever, oedema around eyes, perspiration, muscular pain, chills, prostration, laboured breathing
	Toxoplasma gondii	---	*10–13 days*	Fever, headache, myalgia, rash

Table.2 HACCP Principles and their clarification (Pal *et al.*, 2016)

HACCP principle		Clarification
No	***Principle name***	
1	**Conduct a Hazard Analysis**	Perform a To do this, the team must examine each phase of the hazard analysis process individually, think about potential risks, assess their importance, and choose the most effective way to control them.
2	**Identify Critical Control Points**	Ascertain At this time, the crucial CCPs for product safety have been determined. Either expertise and judgement or a formal technique, such as the Codex decision, can be used to accomplish this.
3	***Establish Critical Limits for each Critical Control Point***	Create Critical limits are safety thresholds that establish the line separating food that is safe from that that may not be. To handle all CCPs, they must be set up.
4	***Establish requirements for monitoring critical control points***	Create a On a daily basis, the monitoring system must show that CCP is under control and be able to identify when control is being lost.
5	***Establish Corrective Action***	Determine that if a CCP is not functioning, remedial action must be performed to safeguard the consumer and to address the reason for the deviation during monitoring. This shows that a specific CCP is not under control.
6	***Establish Verification Procedures***	Create This entails continuously ensuring that the system processes for verification are able to manage pertinent factors to verify that HACCP risks are being implemented and that the system is operating up to date efficiently.
7	***Establish Documentation and Record Keeping***	Establish Documentation will include the principles and their monitoring records, as well as the process documentation pertaining to flow diagrams and tables made for all processes and records throughout the HACCP study (HACCP plans and relevant to these development records).

Figure.1 Types of Biological Food Hazards (source: authors)

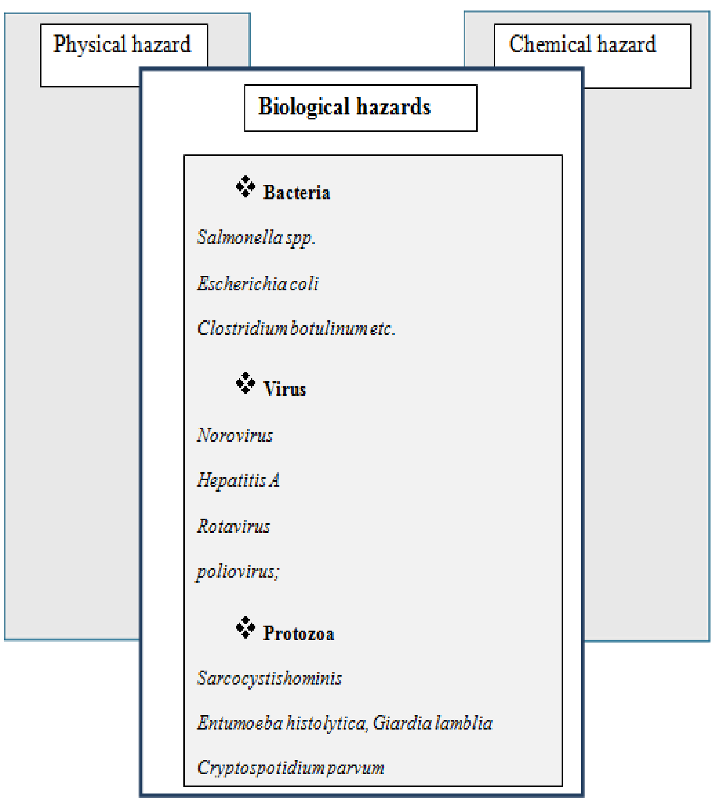

Figure.2 Six steps of social hand washing
(source: mungfali.com, https://surewash.com/news/cleaning-your-hands-correctly-during-covid-19/)

A food safety and management system (FSMS) is defined by the International Standard ISO 22003 as a "collection of interconnected components used to create and accomplish the goals of leading and managing food security and safety organisations". The following are the essential components of FSMS:

Appropriate methods Hazard Analysis and Critical Control Point, or HACCP, is a management tool.
Communication and regulatory needs

HACCP is used by the majority of food industry worldwide to ensure food safety. Due to its methodical adoption of new scientific measures and suitable food safety regulations enforced by the National Food Authority, FSMS has gained popularity both domestically and internationally in addition to HACCP (Attrey, 2017).

The Food Safety and Standards Act (FSSA) was passed in 2006, superseding eight previous legislation (Johnson, 2015).

1. The Prevention of Food Adulteration Act, 1954 (37 of 1954)
2. The Fruit Products Order, 1955
3. The Meat Food Products Order, 1973
4. The Vegetable Oil Products (Control) Order, 1947
5. The Edible Oils Packaging (Regulation) Order, 1998
6. The Solvent Extracted Oil, de-oiled Meal, and Edible Flour (Control) Order, 1967.
7. The Milk and Milk Products Order, 1992.
8. Any other order issued under the Essential Commodities Act, 1955 (10 of 1955) relating to food.

For all food products examined by 21 Scientific Panels and one Scientific Committee made up of different independent experts and scientists, the FSSAI establishes the rules and standards (FSSAI, 2021). All kinds of food chain organisations can use FSMS, which is a little easier to understand than HACCP, because the Bureau of Indian Standards (BIS) adheres to ISO 22000: 2005 (Shafi *et al.,* 2014).

Industrial Treatments for Removal of Microorganism

Thermal treatments are costly and have the disadvantage of changing the physicochemical and/or organoleptic properties of food products, even though they were once the most popular method for getting rid of bacteria. This has led to the rapid development of new technologies that effectively eliminate germs without sacrificing the quality of the product. These technologies include irradiation, high-pressure systems, ultrasounds, and high-intensity pulsed electric fields. A number of increasingly effective disinfection technologies have been created to eradicate microorganisms due to the growing necessity of eliminating undesirable microbes from several industrial processes, especially in the food, agricultural, and pharmaceutical sectors.

New Technologies for Industrial Sterilisation

According to recent estimates, this type of contamination wastes more than 20% of the world's food supply. More people are realising that stronger technology is needed to eradicate microorganisms. These new technologies can also help environmental engineering, as demonstrated below:

Sterilisation of Plasma

The fourth state of matter is frequently referred to as gas plasmas. The plasmas employed for Ionised gases are really used in sterilisation. Plasm sterilisation tests are conducted at temperatures that are close to room temperature and at one of three pressure ranges: atmospheric pressure, medium pressure (0.1 to 10 Torr), or low pressure (1 to 10 mTorr).

System of High Hydrostatic Pressure

Campos and Cristianini (2007) state that high pressure homogenisation can be used to inactivate the bacteria *Lactobacillus plantarum* and *Saccharomyces cerevisiae* in orange juice. This technique is suggested as a good substitute for pasteurising this product.

Radiation

Food irradiation is the process of exposing food items to regulated radiation levels in order to eradicate dangerous parasites. Radiation comes in the following types:

I. X-rays. These rays shouldn't have more energy than 5 MeV.
II. Gamma rays. radioactive decay-produced electromagnetic radiation at dosages less than 10 KGy (Poyatos *et al.,* 2011).
III. Electrons moving more quickly: The energy limit of beta radiation is 10 MeV. These kinds of radiation are used to remove dangerous bacteria from food, delay spoiling, and generally halt its biological activity.

Combination Therapies

Many research are now being conducted that combine various forms of microbial inactivation therapy. In general, adding a thermal treatment improves non-thermal therapies, but without the high temperature required for thermal inactivation (Poyatos *et al.,* 2011).

The Role of Recent Technology and Innovation in Food safety

Technological advancements play an increasingly important role in enhancing food safety. Rapid detection methods can identify microbial contamination quickly, allowing for timely intervention. Advanced packaging technologies can help extend shelf life and prevent microbial growth. Furthermore, block chain technology can improve traceability throughout the food supply chain, enabling faster recall of contaminated products. By deploying new and powerful sensors that enable rapid sensing processes, the food industry can help detect trace adulteration and toxic substances. At present, as a common food safety detection method, lateral flow immunochromatography (LFI) is widely used in food safety testing, environmental testing and clinical medical treatment because of its advantages of simplicity, speed, specificity and low cost, and plays a pivotal role in ensuring food safety (Rahmati *et al.,* 2020).

Using conventional methods in the detection of pathogenic microorganisms in food has no sufficient performance, however, newly established methods like Nano sensors have resolved this problem by rapid detection of pathogenic strains and the identification of their released toxins in all stages of the food production. Food companies uses these type of devices because of their remarkable capacity. Interestingly, Kraft Food Company provides some sorts of Nano crystal sensors that are directly used in the packaging sector of factories. When the food-borne pathogens produce gas due to their activities leading to food spoilage, these highly sensitive devices detect the produced gases, as a result, the packaged food would be placed away from the packaging line. The colour changes in strips inserted on the sensors are a visual signal to detect whether the food is fresh or not, immediately alerting the operators. One of the biggest challenges in food preservation is mass manufacturing. The emergence of multiple drug-resistant (MDR) infectious organisms is a result of antibiotic abuse. Through the application of nanoparticles with antibacterial action, nanotechnology has recently offered a novel method against a variety of MDR pathogens (Rahmati *et al.,* 2020). Emerging technology artificial intelligence contains a number of mechanisms that could be used to generate benefits in a variety of fields. Applications related to artificial intelligence have garnered more attention recently as a way to improve food safety. These applications such as machine learning, computer vision, predictive analytics algorithms, sensor networks, robotic inspection systems, and supply chain optimization tools have been established to contribute to several domains of food safety such as early warning of outbreaks, risk prediction, detection and identification of food associated pathogens (Rugji *et al.,* 2024).

Food safety is a shared responsibility, requiring the concerted efforts of producers, processors, retailers, consumers, and regulatory agencies. By implementing robust food safety practices, we can significantly reduce the burden of foodborne illnesses and ensure a safer food supply for all. Continuous research, innovation, and education are essential to address emerging microbial threats and further strengthen our food safety systems.

Preventing microbiological contamination and safeguarding the health of general public depends on maintaining food safety. In order to lower the risk of foodborne infections, proper hygiene practices—such as hand washing, sanitation, and safe food handling—are essential. By identifying and getting rid of dangerous microorganisms, technological developments in food processing, storage, and monitoring further improve safety. A safer food supply chain is ensured by a mix of stringent food safety laws, adequate cleanliness, and cutting-edge technology, which reduces health risks and enhances general wellbeing. Preventing microbiological dangers and guaranteeing safe consumption need consistent efforts in food safety management.

Preventing microbiological contamination and guaranteeing food safety require the implementation of food safety systems such as HACCP, GMP, and GAPs. GMP guarantees food processing quality and cleanliness, whereas HACCP identifies and manages risks in a methodical manner. In order to stop contamination at its source, GAPs encourage safe farming methods. Furthermore, WHO's Five Keys to Safer Food—using safe water and raw materials, heating food properly, storing food at safe temperatures, and keeping food clean—act as essential guidance. By combining these procedures with stringent laws and education, microbiological dangers are reduced and a safer world food supply is guaranteed. By offering creative ways to identify, manage, and avoid microbiological food dangers, technological developments have begun to completely transform food safety. Technology is essential for reducing hazards, from quick diagnostic tools like PCR and biosensors to food processing methods like pasteurization, irradiation, and high-pressure processing. Food safety from manufacturing to consumption is ensured by smart packaging and block chain technology, which also improve traceability and real-time monitoring.

Author Contributions

Shreya Das: Investigation, formal analysis, writing—original draft. Snehashis Polley: Validation, methodology, writing—reviewing. Sayan Bhattacharyya:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Adams, M. and Moss, M. (1995) Food Microbiology. 2nd Edition, The Royal Society of Chemistry, London.

Alakash, Hekmat & Abu Arrah, Abdelhakeem & Bhatti, Feyza & Maabreh, Roqia & Arrah, Riham. The effect of food safety training program on food safety knowledge and practices in hotels' and hospitals' food services. Italian Journal of Food Safety 2022; 11. https://doi.org/10.4081/ijfs.2022.9914.

Andrade A A, Paiva AD, Machado A B F. Microbiology of street food: understanding risks to improve safety. J Appl Microbiol. 2023;134(8):lxad167. https://doi.org/10.1093/jambio/lxad167.

Attrey, 2017. Role of veterinary experts in food safety, Editor(s): Rajul Kumar Gupta, Dudeja, Singh Minhas, Food Safety in the 21st Century, Academic Press, Pages 297-310, https://doi.org/10.1016/B978-0-12-801773-9.00024-8

Bintsis T. Foodborne pathogens. AIMS Microbiol 2017;3(3):529-563. https://doi.org/10.3934/microbiol.2017.3.529.

Campos, M. Cristianini, 2007. Inactivation of Saccharomyces cerevisiae and Lactobacillus plantarum in orange juice using ultra high-pressure homogenisation, Innovative Food Science & Emerging Technologies, 8, Issue 2, 226-229. https://doi.org/10.1016/j.ifset.2006.12.002

Charpe A, Sedani S, Murumkar R, Bhad R. Effect of temperature on microbial growth in food during storage 2019. www.ycjournal.net. LAST ACCESSED 13/2/25.

De J, Pabst C, Lepper J, Schneider R, Schneider K.. Food Safety on the Farm – An Overview of Good Agricultural Practices. https://edis.ifas.ufl.edu/publication/FS136.

FSSAI, 2021

Gaggia, F., Di Gioia, D., Baffoni, L., & Biavati, B. The role of protective and probiotic cultures in food and feed and their impact in food safety. Trends Food Sci Technol 2011;22, S58–S66

https://surewash.com/news/cleaning-your-hands-correctly-during-covid-19/last accessed 13/2/25.

https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/danger-zon20that% 20cause% 20illness.

https://www.j-humansciences.com/ php/IJHS/article/view/3925.

Kennedy J, Nolan A, Gibney S, O'Brien S, McMahon MAS, McKenzie K, *et al.,*.Deteminants of cross-contamination during home food preparation", British Food J 2011;. 113 (2): 280 – 297.

Meghwal, M, Heddurshetti U, Biradar R. Good Manufacturing Practices for Food Processing Industries: Purposes, Principles and Practical Applications. Food Technol 2017:26. Apple Academic Press.

Mor-Mur, M. and Yuste, J. (2010) Emerging Bacterial Pathogens in Meat and Poultry: An Overview. Food and Bioprocess Technology, 3, 24. https://doi.org/10.1007/s11947-009-0189-8

Northrop-Clewes C A, Shaw C. Parasites. British Medical Bulletin 2000; 56(1): 193–208. https://doi.org/10.1258/0007142001902897

Omemu A M, Aderoju S T. Food safety knowledge and practices of street food vendors in the city of Abeokuta, Nigeria. Food Control 2008;19(4):396–402. https://doi.org/10.1016/j.foodcont.2007.04.021.

Pal M, Aregawi W, Singh R. The role of Hazard Analysis Critical Control Point in food safety. Beverage and Food World 2016; 43: 33-36.

Poyatos J M, Almecija M C, García-Mesa J J, Muñio M M, Hontoria E, Torres J C, Osorio F. Advanced methods for the elimination of microorganisms in industrial treatments: potential applicability to wastewater reuse. Water Environ Res. 2011;83(3):233-46. https://doi.org/10.2175/106143010x12780288628570.

Rahmati F, Hosseini SS, Mahuti Safai S, Asgari Lajayer B, Hatami M. New insights into the role of nanotechnology in microbial food safety. Biotech. 2020;10(10):425. https://doi.org/10.1007/s13205-020-02409-9.

Rugji J, Erol Z, Taşçı F, Musa L, Hamadani A, Gündemir M G, Siddiqui S A. Utilization of AI – reshaping the future of food safety, agriculture and food security – a critical review. Critical Reviews in Food Science and Nutrition 2024; 1–45. https://doi.org/10.1080/10408398.2024.2430749

Shafi A, Ahmad F, Mohammad Z, Zaidi S. Food Laws and Regulations Related to Food Security 2014. https://doi.org/10.1007/978-3-031-51417-3_6.

Singh S, Pandey, V D, Verma V. (2011). BACTERIAL FOOD INTOXICATION. Microbial Toxins Toxigen Microbes (book chapter):215-232

Untermann F. Microbial hazards in food. Food Control 1998;9(2-3): 119–126. https://doi.org/10.1016/s0956-7135(97)00067-4

https://www.who.int/activities/promoting-safe-food-handling/five-key-to-safer-food. last accessed 13/2/25.

How to cite this article:

Shreya Das, Snehasis Polley and Sayan Bhattacharyya. 2025. The Vital Role of Food Safety in Mitigating Microbial Hazards - Review Article. *Int.J.Curr.Microbiol.App.Sci.* 14(02): 122-135.
doi: https://doi.org/10.20546/ijcmas.2025.1402.011