Journal of Nutrition and Human Health Advances
Open Access

REVIEW ARTICLE

Volume 2 - Issue 5

Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors

Okunbi Onasokhare Favour [1], **Owei Joy Ebimoboere** [2], **Asare Bernard Kwame** [3], **Moses Adondua Abah** [4,5]
Micheal Oladosu Abimbola [5,6]

[1] Department of Biological Sciences, College of Basic and Applied Sciences, Mountain Top University, Ibafo, Ogun State, Nigeria

[2] Department of Geography and Environmental Management, Faculty of Social Sciences, Niger Delta University, Delta State, Nigeria

[3] Department of Nutritional, Food and Consumer Sciences, Fulda University of Applied Sciences, Germany

[4] Department of Biochemistry, Faculty of Biosciences, Federal University Wukari, Taraba State, Nigeria

[5] ResearchHub Nexus Institute, Nigeria.

[6] Department of Chemical Sciences, Faculty of Science, Anchor University, Ayobo, Lagos State, Nigeria

***Corresponding author:** Moses Adondua Abah, Department of Biochemistry, Faculty of Biosciences, Federal University Wukari, Taraba State, Nigeria.

Received: 21 August , 2026 | **Accepted:** 28 August, 2026 | **Published:** 04 September ,2026

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., *J. Nutrition and Human Health Advances,* 2(5): dx.doi.org/JNHHA/PP.0015

Abstract

The consumption of fresh produce has increased globally due to its recognized health benefits, yet this trend has brought heightened attention to food safety risks associated with fruits and vegetables. Fresh produce is frequently linked to outbreaks of foodborne illnesses, with contamination occurring at multiple stages of the supply chain. This review comprehensively examines the various pre-harvest and post-harvest factors contributing to the microbiological safety risks of fresh produce. Pre-harvest factors encompass the use of contaminated irrigation water, untreated manure, soil quality, climate, and proximity to animal agriculture, all of which may introduce pathogens such as *Salmonella, E. coli* O157:H7, and Listeria monocytogenes into the production environment. Additionally, poor hygiene practices among farm workers and the presence of wildlife can further exacerbate contamination risks. Post-harvest, produce can encounter hazards during harvesting, washing, packaging, storage, and transportation. Inadequate washing, improper temperature control, and cross-contamination during processing are significant contributors to microbial persistence and growth. The review also addresses the emergence of antimicrobial resistance and the role of biofilms in protecting pathogens on produce surfaces. Integrated management strategies such as implementing Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs), and Hazard Analysis and Critical Control Points (HACCP) systems are crucial for minimizing risks at all stages.

Keywords: food safety; fresh produce; pre-harvest contamination; post-harvest handling; and microbial risk.

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

1.Introduction

Fresh fruits and vegetables are an important part of a healthy and balanced diet (Iwu & Okoh, 2019). The consumption of fresh produce has increased significantly in recent years due to growing awareness of its health benefits (Macieira *et al*., 2021). Global demand for fresh produce continues to rise as consumers increasingly seek minimally processed, convenient, and nutritious food options (Gong *et al*., 2024). Similarly, the increasing preference for minimally processed foods has contributed to greater consumption of fresh-cut produce (Murray *et al*., 2017).

Despite their nutritional importance, fresh produce is often consumed raw, thereby increasing the risk of foodborne illness when contamination occurs (Fatica & Smith, 2011). Consequently, food safety concerns associated with fresh produce have grown substantially, particularly following several high-profile foodborne disease outbreaks linked to fruits and vegetables (Carstens *et al*., 2019). Evidence indicates that fresh produce has become a significant vehicle for the transmission of foodborne pathogens. In Europe, approximately 10% of foodborne outbreaks reported between 2007 and 2011 were linked to fresh produce, accounting for about 35% of hospitalizations and 46% of mortalities associated with these outbreaks (Iwu & Okoh, 2019). Similarly, produce-related outbreaks accounted for 12.3% of all reported foodborne outbreaks between 1990 and 2007, compared to only 0.7% during the 1970s (S294 Project, 2011). Furthermore, approximately 23% of all foodborne illnesses reported between 1998 and 2007 were attributed to fresh produce consumption (S294 Project, 2011).

The global burden of foodborne diseases remains substantial. According to the World Health Organization, unsafe food causes approximately 600 million cases of foodborne diseases and 420,000 deaths annually worldwide (WHO, 2024). Children under five years of age bear a disproportionate share of this burden, accounting for 40% of foodborne disease cases and approximately 125,000 deaths each year (WHO, 2024). In the United States, fresh produce alone accounts for nearly half of all foodborne illnesses, further highlighting the public health significance of produce safety (CDC, 2025).

One of the major challenges in ensuring the safety of fresh produce is the complexity of contamination pathways. The contamination of produce in both pre-harvest and post-harvest environments is difficult to eliminate because these products are frequently consumed as raw and fresh commodities (Fatica & Smith, 2011). At the pre-harvest stage, agricultural soil and irrigation water serve as important reservoirs for clinically significant foodborne pathogenic bacteria and represent major sources of contamination (Iwu & Okoh, 2019). Additionally, contamination can occur during post-harvest handling, including transportation, storage, and processing operations (Carstens *et al*., 2019). Research has demonstrated that the primary production niches within agro-ecosystems play a significant role in the transmission of pathogens associated with fresh produce (Iwu & Okoh, 2019).

This review aims to comprehensively examine the food safety risks associated with fresh produce, with particular emphasis on pre-harvest and post-harvest factors contributing to microbial contamination, the burden of associated foodborne illnesses, and evidence-based strategies for risk mitigation

Food Safety Hazards Associated with Fresh Produce

Classification of Food Safety Hazards

Fresh produce can be contaminated by physical, chemical, and biological hazards (Hussain *et al*., 2017). Physical hazards could include dust, sand, wood and metal pieces (Hussain *et al*., 2017). Safety of vegetables and fruits can be compromised due to the presence of microbiological (bacteria, viruses, parasites, fungi), chemical (mycotoxins, nitrate,) (Macieira *et al*., 2021). Generally, food contamination can be summarized as follows: Biological contamination: Bacteria and fungi are common biological contaminants in foods. Chemical contamination: Pesticide residues in agricultural products are the primary chemical contamination that could cause serious health problems.

Physical contamination: Exogenous foreign substances (from glass pieces to wood chips, stones, and metal pieces) that are not intended to be food components

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

commonly affect food safety (Xie *et al*., 2023). The contamination of foodstuffs by biological hazards, such as bacteria and fungi, can happen at any time between production and consumption (Xie *et al*., 2023). Food risks can be divided into three common forms: physical, chemical, and biological (Surareungchai *et al*., 2022). Main chemical hazards are associated with the presence of endocrine disruptors, heavy metals, and neo-formed chemicals. (Esposito *et al*., 2024).

Table 1. Major food safety hazards associated with fresh produce

Hazard Type	Examples	Sources	Potential Health Effects
Biological	E. coli, Salmonella, Listeria	Soil, water, animals	Foodborne illness
Chemical	Pesticides, heavy metals	Agricultural inputs	Toxicity
Physical	Glass, stones, metal fragments	Handling and processing	Injury

Sources: Xie *et al.* (2023) Esposito *et al.* (2024)

Biological hazards are considered the most significant due to their ability to cause widespread outbreaks and severe illnesses. Chemical hazards pose long-term toxicity risks, while physical hazards primarily cause immediate injury but are generally easier to control through proper handling and inspection.

Major Foodborne Pathogens in Fresh Produce

The most commonly implicated etiological agents in fresh produce borne illnesses are Salmonella spp., Escherichia coli, Campylobacter spp., Listeria monocytogenes... (Alegbeleye *et al*., 2018). Salmonella spp., E. coli O157:H7, and L. monocytogenes are identified as the primary pathogenic microorganisms causing the most concern in such outbreaks (Santos *et al*., 2023). Fresh produce can be contaminated with pathogens by coming in contact with improperly treated manure, contaminated water or soil. (Jagannathan, as cited in sources). Salmonella enterica and Escherichia coli appear to be the most prevalent causative agents of foodborne infection linked to the ingestion of fresh produce (Esmael *et al*., 2023). HMPs' entrance into plant tissues through natural openings (stomata, lenticels), roots, or wounds has been reported in several studies (Esmael *et al*., 2023). Several outbreaks have demonstrated that ready-to-eat foods, fresh produce... are particularly vulnerable when control measures are insufficient (Rathi, 2026).

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

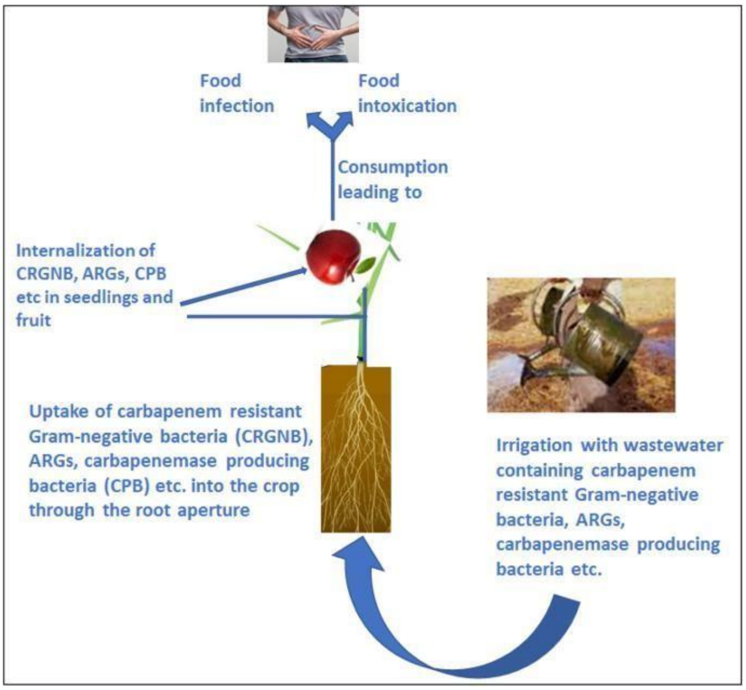

Figure 1. Major microbial contaminants of fresh produce and their transmission routes. As shown in Figure 1, wastewater used for irrigation may contain carbapenem-resistant Gram-negative bacteria (CRGNB), antibiotic resistance genes (ARGs), and carbapenemase-producing bacteria (CPB), which enter crops through root uptake. These contaminants can subsequently internalize within plant tissues, including seedlings and edible fruits. Consumption of contaminated produce may expose consumers to these resistant microorganisms and genes, potentially resulting in food infection or food intoxication and posing significant public health risks.

Source: Founou *et al*. (2020)

Irrigation water and manure-amended agricultural soil represent the two most important transmission pathways of enteric pathogens to fresh produce during the preharvest stage (Iwu & Okoh, 2019). Some of the established bacterial contamination sources include contaminated manure, irrigation water, soil, livestock/wildlife (Alegbeleye *et al*., 2018). On the other hand, the use of raw manure has been linked to a higher prevalence of pathogenic microorganisms in agricultural soils compared to the use of composted manure (López-Gálvez *et al*., 2021). Untreated animal manure was the most common cause of pre-harvest spread of ARB in fresh produce (Rahman *et al*., 2021). Soil and manure have both played major roles in exposing plants to a diverse array of microflora comprised of both beneficial and harmful microorganisms (Jagannathan, 2019). Application of manure to production fields may result in persistence of microorganisms in the environment for extended periods of time, thereby increasing the risk of contamination of the produce (Jagannathan, 2019).

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

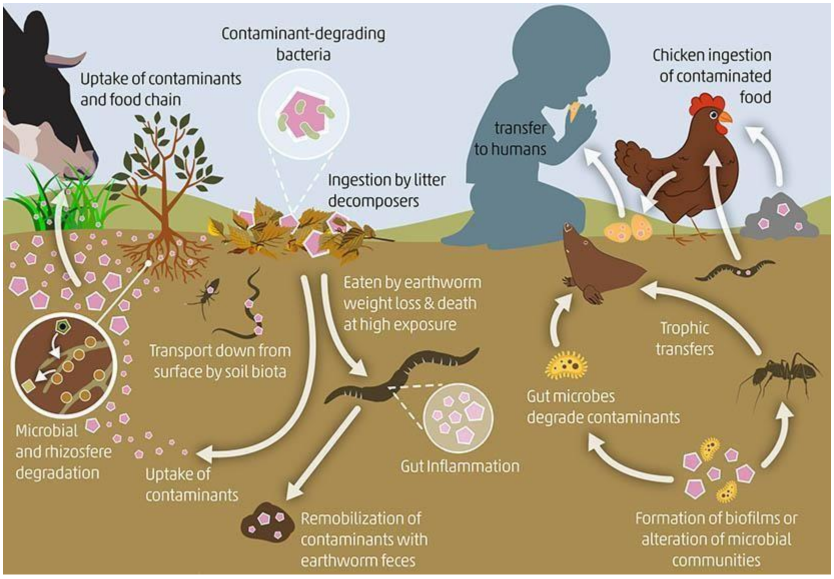

Figure 2.Pre-harvest sources of contamination in agricultural fields. As shown in Figure 2, contaminants present in soil can undergo microbial transformation, degradation, transport, and bioaccumulation within terrestrial ecosystems. Plants may absorb contaminants through their roots, leading to accumulation in edible tissues and entry into the food chain. Soil organisms such as earthworms, insects, and decomposers facilitate contaminant movement through feeding activities, bioturbation, and fecal remobilization. Contaminants may also undergo trophic transfer to livestock and poultry, ultimately reaching humans through the consumption of contaminated plant and animal products. These interconnected pathways highlight the role of soil ecosystems in the persistence, transport, and transmission of environmental contaminants to humans.

Source: Waring *et al.* (2020**)**

Contaminated irrigation water is considered the most important risk factor for preharvest produce contamination (Sela Saldinger *et al*., 2023). Irrigation water is a potential transmission route of fresh produce contaminants (Iwu & Okoh, 2019). The risk of crop contamination in field cultivation depends upon the water quality, irrigation method, crop type, and water source (Sela Saldinger *et al*., 2023). Surface water exposed to runoff from livestock operations or sewage is more likely to be contaminated than groundwater. Overhead irrigation is considered the riskiest because the direct contact between the water and the edible portion of the crop leads to bacterial retention and colonization on the plant surface (Sela Saldinger *et al*., 2023). Surface water generally presents higher contamination potential due to exposure to environmental pollutants and animal waste, while groundwater tends to have lower risk but can still become contaminated through poor well management. Treated wastewater offers a sustainable option but requires strict monitoring to minimize food safety risks as summarized Table 2

Table 2. Irrigation water sources and associated food safety risks

Water Source	Common Contaminants	Risk Level
Surface water	Salmonella, E. coli, Norovirus	High
Groundwater	Lower microbial load	Low-Moderate

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

Treated wastewater	Heavy metals, residual pathogens	Moderate-High

Potential sources for foodborne pathogens are fecal materials and soil, irrigation water, improperly composted manure, air, wild and domestic animals, birds, rodents and flies (Alegbeleye *et al*., 2018). Wildlife intrusion and livestock proximity contribute significantly to fecal contamination of produce fields (Various pre-harvest studies). Proximity of fresh produce to contaminated soil and enteric pathogen sources increases risk (Preharvest farming practices reviews).

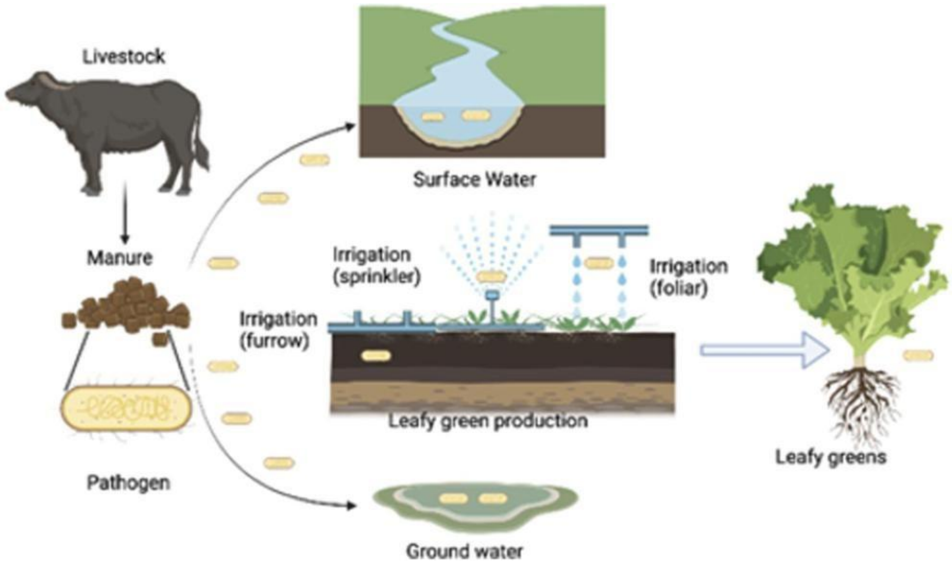

Figure 3. Environmental drivers of pre-harvest produce contamination. Figure 3 shows clearly the ecological pathways of contamination involve animals acting as reservoirs that introduce pathogens through direct fecal deposition or runoff, which then interact with soil, water, and crops under varying climatic conditions that influence pathogen survival and spread

Source: Santos *et al*. (2023)

Post-Harvest Factors Influencing Food Safety Risks

In the post-harvest phase, various factors can contribute to contamination. These include the use of contaminated ice or water, inadequate hygiene practices by handling staff or consumers, damage to plant tissues, issues with transport equipment, the presence of animals or pests in the environment, water quality during production and processing, use of contaminated equipment, cross-contamination, and improper storage conditions (Santos *et al*., 2023). During harvesting, the contamination of products is exacerbated by poor hygiene practices among rural workers and the lack of sanitation facilities (Santos *et al*., 2023). Fresh produce can also be contaminated through harvesting equipment, processing plants, field workers, and trading processes along the farm to table continuum at the postharvest stage (Iwu & Okoh, 2019). Poor hygiene by fieldworkers, use of mobile toilets and hand-washing stations increase the risk of pathogen dissemination at pre-harvest and during harvest (Ehuwa *et al*., 2021). After harvest, contamination of produce is mainly due to poor hygienic practices (Ehuwa *et al*., 2021).

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

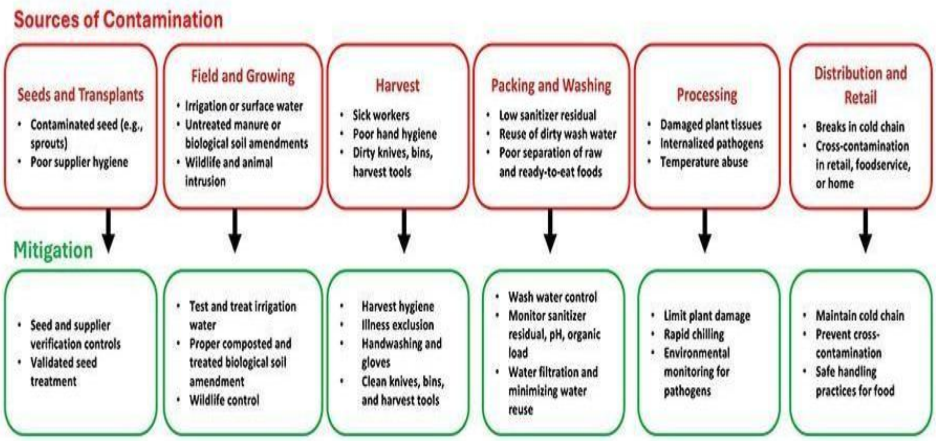

Figure 4. Post-harvest contamination pathway during harvesting and handling. The above figure, highlights critical control points at every stage from harvesting through retail. Worker hygiene, equipment sanitation, and prevention of cross-contamination during transport and washing represent key intervention points to minimize microbial risks.

Source: Rahman *et al*. (2021)

Improper handling of fresh produce during post-harvest processing, including cutting, washing or sanitizing, transporting, packaging or storing, can also create opportunities for microbial cross-contamination (Rahman *et al*., 2021). Post-harvest washing that was once considered decontamination is now viewed as a high-risk cross-contamination point (Murray *et al*., 2017). The challenges in monitoring the post-harvest wash process will be discussed along with processing factors that need to be considered (Murray *et al*., 2017). To prevent post-harvest contamination, studies suggested that: (1) standard sanitation and hygienic practices should be followed by all stakeholders who are involved in food production and supply chain; (2) unsafe or contaminated water used to wash and sprinkle over the fruits and vegetables by the vendors should be regulated and monitored to avoid potential cross-contamination (Rahman *et al*., 2021). As summarized in Table 3 Intervention strategies such as the use of approved sanitizers and controlled washing conditions show moderate effectiveness when properly maintained. However, their success depends heavily on water quality, sanitizer concentration, and prevention of biofilm formation on equipment.

Table 3. Post-harvest processing steps and associated risks

• Processing Step	• Major Hazard	• Control Measure
• **Washing**	• Cross-contamination	• Use of potable water and sanitizers
• **Cutting/Processing**	• Pathogen internalization	• Sanitary equipment and worker hygiene
• **Packaging**	• Microbial growth	• Proper temperature and materials

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

Source: Rahman *et al*. (2021)

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

In the post-harvest phase, various factors can contribute to contamination, including improper storage conditions (Santos *et al*., 2023). The proper transport of fresh produce from farm to market will help reduce the potential for microbial contamination (FDA Guidance). Keep transportation vehicles clean to help reduce the risk of microbial contamination of fresh produce (FDA Guidance).

Food Safety Management and Control Strategies

Good Agricultural Practices (GAPs)

Good Agricultural Practices (GAP) are a collection of principles applied to on-farm production and post-harvest processes to ensure food safety (Soon *et al*., 2023). GAPs aim to reduce microbial contamination of fresh produce by implementing preventive measures at the farm level (Soon *et al*., 2023). The application of GAP includes proper management of soil, water, manure, and worker hygiene to minimize the introduction of pathogens (Olaimat *et al*., 2020). Implementation of GAP has been shown to significantly reduce the risk of foodborne pathogen contamination in fresh produce (Olaimat *et al*., 2020). Preventive farm-level interventions under GAP focus on source control of potential contaminants before they reach the produce (Olaimat *et al*., 2020).

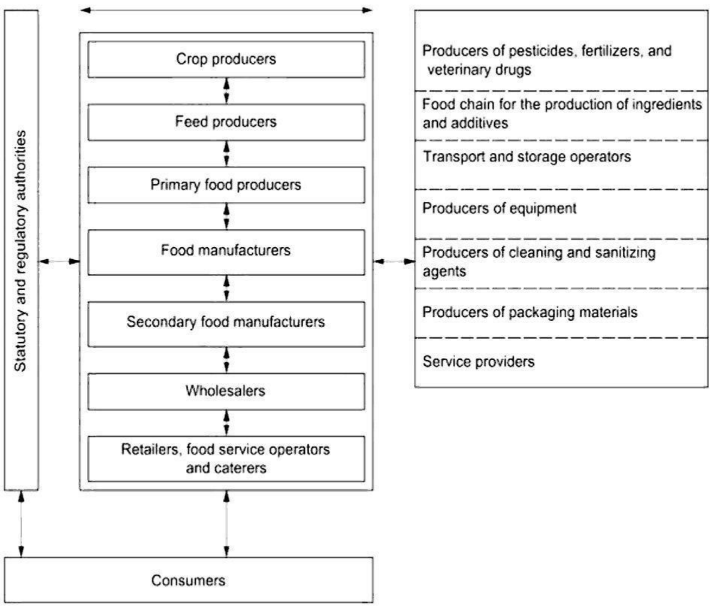

Figure 5. Food safety control framework from farm to consumer. Figure 5 shows Integrated food safety management requires coordinated interventions at every stage of the supply chain. GAP forms the foundation at the farm level, ensuring that preventive controls flow through subsequent stages to achieve comprehensive risk reduction from production to consumption.

Source*:* Soon *et al*. (2023)

Good Manufacturing Practices and HACCP Systems

Hazard Analysis and Critical Control Points (HACCP) is a systematic preventive approach to food safety that identifies, evaluates, and controls hazards (Trienekens & Hvolby, 2022). HACCP principles are increasingly applied to fresh produce processing to manage microbial risks **table 4** (Trienekens & Hvolby, 2022). The seven principles of HACCP include hazard analysis, identification of critical control points, establishment of critical limits, monitoring procedures, corrective actions, verification, and record-keeping. Application of HACCP in produce safety enables systematic identification and control of hazards throughout the production chain. It shifts focus from end-product testing to preventive control measures, significantly improving the microbial safety of fresh produce when properly implemented (Trienekens & Hvolby, 2022)

Table 4. HACCP critical control points in fresh produce production

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

Processing Stage	Hazard	Critical Control Point
Washing	Microbial contamination	Sanitizer concentration & contact time
Cooling	Temperature abuse	Rapid cooling to proper temperature
Packaging	Cross-contamination	Equipment sanitation & material quality

Source: Trienekens & Hvolby (2022)

Emerging Technologies for Produce Safety

Emerging technologies such as biosensors, UV treatment, ozone, and AI-based monitoring systems offer promising solutions for enhancing fresh produce safety (Olaimat *et al*., 2020). Biosensors provide rapid, on-site detection of pathogens in produce (Recent MDPI sensor studies). Non-thermal technologies like UV and ozone treatment can effectively reduce microbial load without compromising produce quality (Olaimat *et al*., 2020). Future technological development in produce safety will likely focus on integrating these tools into existing systems. Combining rapid detection with non-thermal decontamination and predictive analytics offers a multi-layered approach to significantly enhance food safety while maintaining nutritional quality and sustainability (Olaimat *et al*., 2020).

Table 5. Emerging technologies for fresh produce safety

Technology	Application	Benefits
Biosensors	Pathogen detection	Rapid diagnosis
UV treatment	Surface disinfection	Reduced contamination
Ozone treatment	Produce sanitation	Improved shelf life
AI monitoring	Risk prediction	Early warning

Source: Olaimat *et al*. (2020)

Challenges and Future Perspectives

The globalization of food supply chains has increased the movement of fresh produce across international markets, creating new opportunities for trade while simultaneously increasing food safety challenges. Fresh produce is increasingly recognized as a source of foodborne outbreaks, and the complexity of global supply

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

chains can complicate traceability and outbreak investigations (López-Gálvez *et al*., 2021). The globalization of the food supply chain further complicates produce safety because extended transport and storage durations increase the window for microbial proliferation and cross-border contamination (Moustafa *et al*., 2025). Food production chains and food markets are experiencing exponential growth, making food safety an increasing global concern, particularly for fresh fruits

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

and vegetables consumed without heat treatment (Santos *et al*., 2023). Fresh produce companies involved in international export markets are often subjected to stricter food safety requirements than those serving local markets, highlighting the influence of globalization on food safety management systems (López-Gálvez *et al*., 2021). The increasing interconnectedness of global food systems means that contamination occurring in one region can rapidly affect consumers in multiple countries, emphasizing the need for improved international cooperation, traceability systems, surveillance programs, and harmonized regulatory frameworks (López-Gálvez *et al*., 2021; Santos *et al*., 2023).

Climate change has emerged as a major global issue with significant implications for foodborne pathogens and food safety (Awad *et al*., 2024). Increases in mean air temperatures, altered precipitation patterns, drought events, flooding, and other extreme weather conditions are expected to influence the occurrence and transmission of foodborne pathogens throughout agricultural environments (López-Gálvez *et al*., 2021; Awad *et al*., 2024). Climate-related changes may increase the presence of pathogenic microorganisms in foods, including fresh vegetables (López-Gálvez *et al*., 2021). Studies have suggested that rising temperatures and changes in precipitation patterns may affect contamination sources and pathogen transmission pathways, potentially increasing contamination of fresh produce with pathogenic microorganisms (López-Gálvez *et al*., 2021). Flooding events have been associated with pathogenic contamination of leafy green vegetables, while drought-stressed plants may become more susceptible to pathogen internalization (López-Gálvez *et al*., 2021). Climate change can also influence pathogen persistence through its effects on temperature, rainfall, and drought cycles, thereby reshaping the microbial safety landscape of fresh produce (Moustafa *et al*., 2025). These developments indicate that adaptation and mitigation strategies will be increasingly necessary to reduce the impacts of climate change on fresh produce safety and public health (López-Gálvez *et al*., 2021; Awad *et al*., 2024).

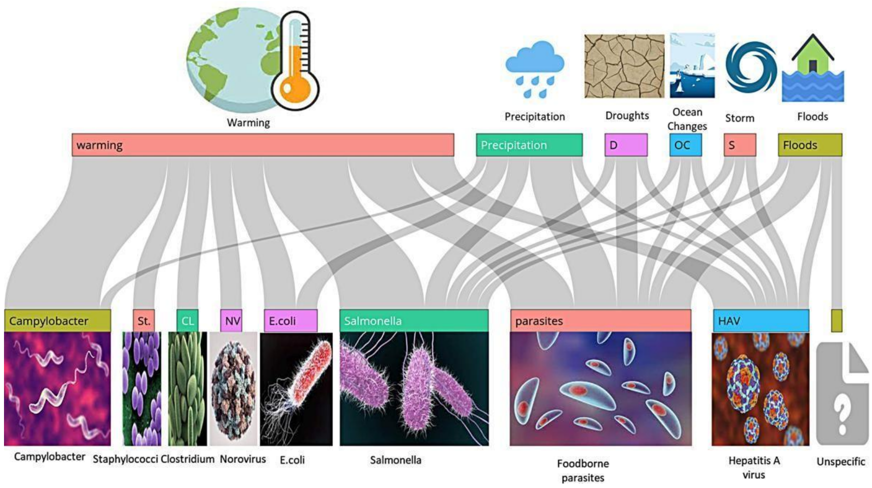

Figure 6. Emerging Challenges Affecting Fresh Produce Safety. Figure 6 depicts that future food safety threats are expected to become increasingly interconnected. Climate change may alter pathogen ecology and water availability, globalization may facilitate the international spread of contaminated products, and antimicrobial resistance may increase the severity of foodborne infections. These interacting challenges highlight the need for integrated food safety management approaches that combine environmental, agricultural, public health, and regulatory interventions

Sources: López-Gálvez *et al*. (2021)

.Antimicrobial resistance (AMR) is another major emerging challenge affecting fresh produce safety. Fresh fruits and vegetables may serve as vehicles for antimicrobial-resistant bacteria and antimicrobial resistance genes that can be transmitted to humans

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

through the food chain (Kalpana *et al*., 2024). Contamination of fresh produce with antibiotic-resistant bacteria has become a growing public health concern because resistant microorganisms may persist throughout agricultural ecosystems and food production environments (Kalpana *et al*., 2024). Irrigation water, soil, manure, wildlife, and post-harvest handling

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

practices have all been identified as potential sources of antimicrobial-resistant microorganisms associated with fresh produce (Kalpana *et al*., 2024). The occurrence of multidrug-resistant Escherichia coli, Salmonella spp., Klebsiella spp., and other clinically important bacteria on fruits and vegetables intended for raw consumption has been reported in numerous studies (Kalpana *et al*., 2024). The continued emergence of antimicrobial resistance may increase disease burden, complicate treatment options, and reduce the effectiveness of current public health interventions, thereby representing a significant future threat to food safety systems worldwide (Kalpana *et al*., 2024).

Regulatory differences among countries continue to present challenges for effective food safety governance. Variations in microbiological standards, inspection procedures, surveillance systems, certification requirements, and enforcement capacities may create inconsistencies throughout international supply chains (López-Gálvez *et al*., 2021). Different countries frequently apply different approaches to food safety management, resulting in challenges for producers, exporters, regulators, and consumers operating within globalized markets (Santos *et al*., 2023). The increasing complexity of international food systems has highlighted the importance of coordinated regulatory frameworks and risk-based approaches that facilitate both trade and food safety protection (Santos *et al*., 2023). Strengthening collaboration among governments, regulatory agencies, and international organizations will be essential to improve harmonization and ensure consistent food safety standards across borders (López-Gálvez *et al*., 2021; Santos *et al*., 2023).

Consumer awareness and behavior remain important determinants of fresh produce safety. At the retail and household levels, improper refrigeration, inadequate washing practices, poor personal hygiene, and cross-contamination between fresh produce and raw animal products can contribute to foodborne illness risks (Moustafa *et al*., 2025). Consumers often fail to adequately wash fresh produce or maintain proper separation between ready-to-eat foods and raw foods during preparation, creating opportunities for pathogen transmission within domestic kitchens (Moustafa *et al*., 2025). Fresh fruits and vegetables are widely perceived as healthy foods, yet many consumers remain unaware of the microbial risks associated with raw consumption (Santos *et al*., 2023). Education and training of all stakeholders throughout the produce supply chain, including consumers, are considered critical components of future food safety strategies (López-Gálvez *et al*., 2021). Future efforts should focus on improving public awareness regarding safe handling, storage, preparation, and consumption practices while integrating emerging technologies, surveillance systems, and risk communication strategies to enhance overall food safety outcomes (López-Gálvez *et al*., 2021; Santos *et al*., 2023; Moustafa *et al*., 2025).

Conclusion

Fresh produce remains an essential component of a healthy diet; however, its consumption is associated with significant food safety challenges arising from both pre-harvest and post-harvest contamination pathways. Major pre-harvest risks include contaminated soil, untreated or improperly composted manure, poor irrigation water quality, wildlife intrusion, livestock proximity, and environmental factors that facilitate the introduction and persistence of foodborne pathogens. Post-harvest contamination may occur during harvesting, washing, processing, packaging, storage, transportation, retail handling, and consumer preparation practices. Because many fruits and vegetables are consumed raw or minimally processed, contamination introduced at any point along the supply chain may directly impact consumer health.

Effective management of these risks requires an integrated food safety approach that addresses contamination from farm to fork. Preventive strategies such as Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs), and Hazard Analysis and Critical Control Point (HACCP) systems play critical roles in minimizing microbial hazards throughout production and distribution. The successful implementation of these measures depends on coordinated efforts among farmers, processors, distributors, regulatory authorities, retailers, and consumers.

Looking forward, strengthening surveillance systems and enhancing pathogen monitoring programs will be essential for early detection and prevention of foodborne outbreaks. The adoption of emerging technologies,

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

including biosensors, artificial intelligence-based monitoring systems, rapid diagnostic tools, and non-thermal decontamination methods, offers promising opportunities to improve produce safety while maintaining product quality and sustainability. At the same time, challenges associated with globalization, climate change, antimicrobial resistance, and regulatory variability will continue to shape the future food safety landscape. Addressing these challenges will require sustained investment in research, technological innovation, international collaboration, and consumer education to ensure the continued safety, quality, and availability of fresh produce worldwide.

Authors' Contributions

The authors of this research have significantly contributed to the study's conception, data collection, and manuscript development. All authors were involved in writing the manuscript or critically reviewing it for its intellectual value. They have reviewed and approved the final version for submission and publication and accept full responsibility for the content and integrity of the work.

Acknowledgement

We thank all the researchers who contributed to the success of this research work.

Conflict of Interest

The authors declared that there are no conflicts of interest.

Funding

No funding was received for this research work

References

1. Soon, J. M., *et al*. (2023). Good Agricultural Practices (GAP) for fresh produce safety. Food Control, 145, 109412. https://doi.org/10.1016/j.foodcont.2022.109412
2. Olaimat, A. N., *et al*. (2020). Emerging technologies for enhancing microbiological safety of fresh produce. Trends in Food Science & Technology, 99, 82–95. https://doi.org/10.1016/j.tifs.2020.02.019
3. Trienekens, J., & Hvolby, H. H. (2022). HACCP implementation in fresh produce supply chains. Journal of Food Protection.
4. Various recent MDPI publications on biosensors and non-thermal technologies in food safety (2022–2024).
5. Santos, M. I., *et al*. (2023). One Health Perspectives on Food Safety in Minimally Processed Vegetables. *Microorganisms, 11*(12), 2990.
6. Iwu, C. D., & Okoh, A. I. (2019). Preharvest transmission routes of fresh produce associated bacterial pathogens with outbreak potentials: A review. *International Journal of Environmental Research and Public Health, 16*(22), 4407.
7. Ehuwa, O., *et al*. (2021). Salmonella, Food Safety and Food Handling Practices. *Foods, 10*(5), 907.
8. Rahman, M., *et al*. (2021). Contamination of Fresh Produce with Antibiotic-Resistant Bacteria and Associated Risks. *International Journal of Environmental Research and Public Health, 19*(1), 360.
9. Murray, K., *et al*. (2017). Challenges in the microbiological food safety of fresh produce: Limitations of post-harvest washing and the need for alternative interventions. *Food Quality and Safety, 1*(4), 289–301.
10. U.S. Food and Drug Administration (FDA). (1998/updated). Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables.tials: A review. *International Journal of Environmental Research and Public Health, 16*(22), 4407.
11. Macieira, A., *et al*. (2021). Food safety in local farming of fruits and vegetables. *International Journal of Environmental Research and Public Health*.
12. Gong, D., *et al*. (2024). Preharvest and postharvest factors improving horticultural products. *Horticulturae*.
13. Murray, K., *et al*. (2017). Challenges in the microbiological food safety of fresh produce. *Food Quality and Safety*.

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

14. Fatica, M. K., & Smith, M. A. (2011). Salmonella and produce: Survival in the plant environment and implications for food safety. *Virulence*.
15. Carstens, C. K., *et al*. (2019). Multistate outbreaks of foodborne illness in the United States. *Frontiers in Microbiology*.
16. World Health Organization. (2024). Food safety. https://www.who.int/news-room/fact-sheets/detail/food-safety
17. Centers for Disease Control and Prevention. (2025). Foodborne illness source estimates.
18. Hussain, M., *et al*. (2017). Food safety risks in fresh produce supply chain. *Food Control*.
19. Macieira, A., *et al*. (2021). Food safety in local farming of fruits and vegetables. *International Journal of Environmental Research and Public Health*, 18(12), 6458. https://doi.org/10.3390/ijerph18126458
20. Xie, Y., *et al*. (2023). Food safety issues and control measures in fresh produce. *Foods*, 12(5), 1023. https://doi.org/10.3390/foods12051023
21. Surareungchai, W., *et al*. (2022). Hazards in fresh produce: A review. *Journal of Food Safety*.
22. Esposito, S., *et al*. (2024). Chemical and biological hazards in vegetables. *MDPI Agriculture*.
23. Alegbeleye, O. O., *et al*. (2018). Microbial safety of fresh produce. *Comprehensive Reviews in Food Science and Food Safety*, 17(6), 1395–1420. https://doi.org/10.1111/1541-4337.12392
24. Santos, M. I., *et al*. (2023). Pathogens in fresh produce outbreaks. *Frontiers in Microbiology*.
25. Esmael, A., *et al*. (2023). Internalization of foodborne pathogens in fresh produce. *MDPI Microorganisms*.
26. Alegbeleye, O. O., *et al*. (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. *Food Microbiology, 73*, 177–208. https://doi.org/10.1016/j.fm.2018.01.003
27. López-Gálvez, F., *et al*. (2021). Interactions between microbial food safety and environmental sustainability in the fresh produce supply chain. *Foods, 10*(7), 1655. https://doi.org/10.3390/foods10071655
28. Rahman, M., *et al*. (2021). Contamination of fresh produce with antibiotic-resistant bacteria and associated risks. *International Journal of Environmental Research and Public Health, 19*(1), 360.
29. Jagannathan, B. V. (2019). The need for prevention-based food safety programs for fresh produce. *Food Protection Trends*.
30. Sela Saldinger, S., *et al*. (2023). Hydroponic agriculture and microbial safety of vegetables. *Horticulturae, 9*(1), 51. https://doi.org/10.3390/horticulturae9010051

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015

Citation: Okunbi Onasokhare Favour , Owei Joy Ebimoboere , Asare Bernard Kwame , Moses Adondua Abah ,Micheal Oladosu Abimbola (2026) Food Safety Risks Associated with Fresh Produce: A Review of Pre- and Post-Harvest Factors., J. Nutrition and Human Health Advances, 2(5): dx.doi.org/JNHHA/PP.0015