International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(REVIEW ARTICLE)

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Global food safety policies: Standards, challenges, and compliance

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International Journal of Science and Research Archive, 2025, 15(03), 439-451

Publication history: Received on 28 April 2025; revised on 05 June 2025; accepted on 07 June 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.15.3.1747

Abstract

Food safety is a critical global public health priority that encompasses the proper management, preparation, and storage of food to prevent contamination and foodborne diseases (FBDs). To ensure food safety in the linked globe of today, international collaboration and robust regulatory systems are very vital. Examining significant standards, new issues, and strategies for ensuring compliance helps this study of international food safety rules to be comprehensive. Foodborne diseases impact about 600 million people annually, and primarily in underdeveloped areas over 420,000 people die from them. Among the major issues the paper highlights are new chemical contaminants (such as PFAS and microplastics), food fraud, antibiotic resistance, global warming, and disconnected regulatory systems. It also looks at the World Health Organisation, the Food and Agriculture Organisation, the Codex Alimentarius, the SPS Agreement of the World Trade Organisation, and ISO 22000 international frameworks and bodies guiding global projects to guarantee food safety. Effective surveillance systems, traceability technologies, and digital innovations are key methods for raising risk detection and compliance. Three of the Sustainable Development Goals (SDGs) this paper focused on health, hunger, and responsible consumption that relate to food safety. Among the recommendations are those for increasing global cooperation, funding laboratory and monitoring capability, harmonising regulations, and combining public health initiatives with food safety campaigns. Food safety determines public health, economic development, and sustainability; so, the outcomes reveal more than just a technical or legal challenge.

Keywords: Global Food Safety; Foodborne Diseases; Codex Alimentarius; Food Policy; International Trade; Antimicrobial Resistance; Food Fraud; PFAS; SDGs; Food Regulation; Food Surveillance; ISO 22000

1. Introduction

Food safety is the management, preparing food, and storage of food so that foodborne disease and contamination is avoided. From farm to table, it covers a broad spectrum of techniques meant to guarantee that the food we eat is safe, wholesome, and free from toxins [1]. Food safety is a worldwide concern influencing every stage of the supply chain in the linked world of today, not only a public health matter. Promoting health, ward against sickness, and guarantee general well-being all depend on safe food. It enhances food markets, fosters consumer confidence, and helps nations' economy to grow. Without appropriate safety precautions, the food we consume may include dangerous bacteria, viruses, parasites, or chemical compounds capable of causing over 200 distinct diseases, ranging from mild gastroenteritis to fatal disorders [2].

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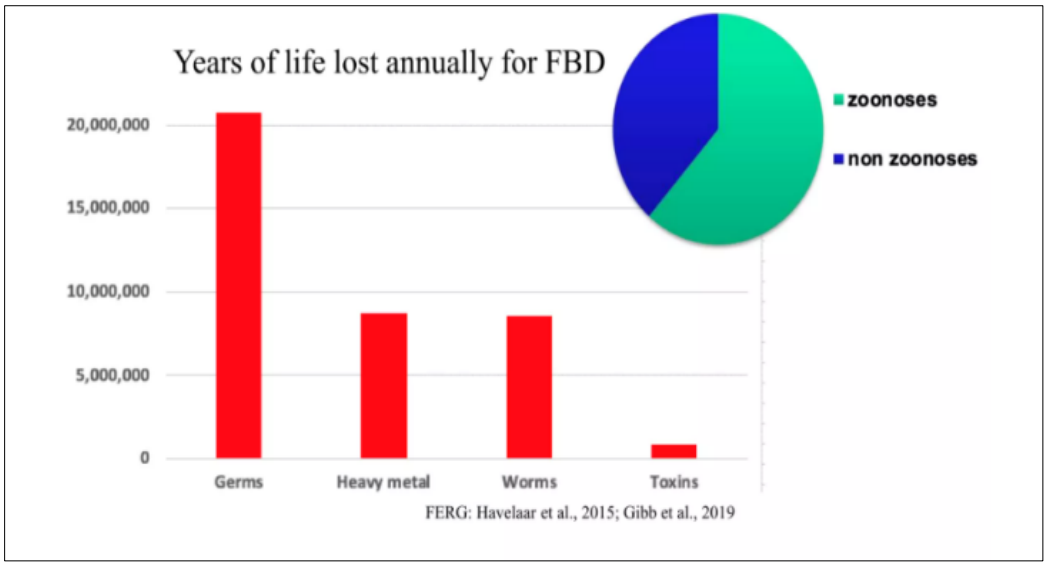

Figure 1 Years of life annually for FBD

Figure 1 shows the global yearly count of food-borne diseases (FBD). Germs have been blamed over 20 million years; then, almost 10 million years for worms and heavy metals. Toxins have minimal influence. As the pie chart shows, zoonoses account for most of food-borne diseases (FBD). Other estimates place 31 recognised hazards at causing 600 million diseases, 480,000 deaths, and 41 million disability-adjusted life years (DALYs). One in six Americans are at high risk; in Greece, one in three; in Africa, it could be as high as one in ten people [3].

Eating dangerous food has far-reaching, grave effects. Foodborne diseases (FBD) can cause major sickness and death particularly in vulnerable groups including children, the elderly, and people with compromised immune systems. The World Health Organisation (WHO) estimates 600 million illnesses and 420,000 deaths annually from contaminated food. Many of these casualties are little children less than five years old. The weight transcends medical problems. Eating tainted food causes illness that damages the economy, reduces work, and results in hefty costs for healthcare systems. Facebook's impact is thought to be costing low- and middle-income countries nearly $95 billion annually. Furthermore, negatively affecting international trade are exporters and farmers losing a lot of money when nations forbid imports owing to safety issues [4].

Among the several UN Sustainable Development Goals (SDGs) food safeties helps to meet: goals 2 (no hunger), 3 (good health and well-being), and 12 (responsible consumption and production). Achieving zero hunger is unattainable without a consistent food supply as having access to food also implies having access to safe food. Encouragement of safe food habits enhances nutritional value and health effects, hence lowering the worldwide disease load. Promoting ethical manufacturing, processing, and distribution methods helps food systems be more sustainable [5]. Thus, guaranteeing the safety of our food supply is not just a general objective but also a foundation of sustainable development in all its manifestations.

Uniform rules are becoming more important since the global food supply chain gets more complex and raw ingredients and completed goods may cross many borders. Food safety is a global duty since a product created in one nation can wind up in the hands of another before being eaten in still another. This interdependence calls for open risk communication between nations, generally accepted norms, and robust international collaboration. But because other countries' regulatory systems are so different, food safety enforcement suffers gaps, compliance is difficult, and generalised uncertainty results. Effective control of these hazards via a worldwide coordinated inspection and monitoring system depends on cooperation and policy alignment. Food safety has to be seen as a shared global concern needing constant attention, creativity, and international cooperation as everyone, wherever they reside, has access to safe food [6].

2. Key Global Organizations and Frameworks in Food Safety

Ensuring food safety calls for coordinated efforts spanning boundaries, industries, and disciplines worldwide. To advise, track, and improve food safety systems all around, several international agencies and frameworks have been created. These agencies help nations in need technically, create standards, and enable information flow. Their combined goals are to lower the load of foodborne diseases, back fair-trade policies, and inspire confidence in the world's food supply. The most powerful worldwide organisations and models below help to create international food safety regulations and practices.

2.1. Codex Alimentarius Commission

Key player in the global system assuring food safety is the Codex Alimentarius Commission, co-founded in 1963 by the FAO and the WHO. From sanitation and labelling to additives and contaminants, the Codex is a comprehensive collection of globally recognised standards, recommendations, and guidelines of practice covering the complete food production and commerce process. Although they are entirely optional, the Codex guidelines form the scientific basis for many national food rules and are much relied upon in international trade conflicts before the World Trade Organisation. Regarding protecting consumer health and advancing fair business practices in the food industry, the commission is absolutely vital. Having approximately 180 members, it advocates consensus-driven policies grounded on the most current scientific data. For nations lacking strong legal systems to build or improve food safety infrastructure, Codex offers a helpful basis. Basically, Codex is a global benchmark that nations can consult for direction on how to satisfy safety criteria [7].

2.2. WHO and FAO

Outside of their work with Codex, Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) are both very involved in bigger food safety campaigns. The World Health Organisation (WHO) concentrates on the public health part of food safety in three ways: hosting World Food Safety Day, providing statistics on foodborne disease outbreaks, and providing risk assessment and surveillance system guidelines. Especially in low-income countries, the World Health Organisation (WHO) monitors the financial effect of food poisoning on healthcare systems all over. Regularly, they publish estimates of the worldwide burden of food poisoning [8].

On the other hand, the Food and Agriculture Organisation mostly concentrates on agricultural methods and food production. Cooperation among governments seeks to increase agricultural standards, lower food waste, and support long-term plans to prevent pollution before it starts. Using its farm-to-- fork strategy, FAO seeks to protect the food supply chain including soil and water quality, pesticide use, and veterinary practices.

Countries trying to strengthen their food safety systems may rely on the WHO and FAO working together for comprehensive support. Their cooperation is particularly crucial in reaction to crises since both of them supervise the global warning system for food poisoning outbreaks.

2.3. ISO 22000 Standardization

Food safety is also significantly influenced by the International Organisation for Standardisation (ISO), particularly through its ISO 22000 standard. An extensive Food Safety Management System (FSMS) that incorporates the concepts of Hazard Analysis and Critical Control Points (HACCP) and other quality management techniques is required to achieve this internationally acknowledged certification [9].

Each link in the food supply chain from producers and processors to distributors and retailers can benefit from the tools provided by ISO 22000, which aid in the detection, evaluation, and mitigation of potential threats to consumer health and safety. Private enterprises seeking to show their dedication to food safety and quality frequently embrace ISO standards, in contrast to Codex, which is mostly utilised by public regulators and governments.

The universal applicability of ISO standards is their greatest strength. In order to facilitate trade and transparency, ISO 22000 unites food enterprises worldwide under a standard management framework. In order to better satisfy both domestic and foreign regulators and customers, businesses should strive to become ISO 22000 compliant.

2.4. World Trade Organization (WTO)

Food safety affects not only the general health of the people but also the seamless operation of world trade. A vital instrument in the World Trade Organisation (WTO) toolkit for striking a balance between fair market access and food

safety is the SPS Agreement. Under the SPS Agreement, every nation is free to create its own food safety rules; long as they are grounded in sound research and do not unfairly target any one group, then so is true [10].

Under this agreement, no nation will be able to impose trade restrictions based on food safety concerns acting as a pretext. It encourages in dispute resolution transparency, harmony, and teamwork. Significantly, it gives Codex recommendations additional weight since it recognises them as the gold standard for food safety in world trade.

The SPS Agreement also promotes technical assistance and capacity building to help underdeveloped countries fulfil international criteria and get access to world markets. Consequently, the World Trade Organisation (WTO) structure ensures that trade is equitable based on scientific data and grounded on facts, so safeguarding consumers.

3. International Legal and Regulatory Structures

The objective of global food safety regulations is to facilitate the safe exchange of foodstuffs, engender trust in consumers, and protect the public's health. Despite the variability in form and intensity of these regulations, their objective remains the same. While some communities struggle with financing, knowledge, and enforcement, others have rather sophisticated and developed food safety systems. Examining the regulatory policies of important world players helps one to gain understanding of the management of food safety on a national and regional level as well as the initiatives taken by international trade agreements to promote cooperation and uniformity across borders.

Regarding food safety, the European Union (EU) boasts among the most sophisticated and linked systems available worldwide. Important to this system is the EFSA, an autonomous scientific agency providing recommendations on food-related hazards. Regarding public health, EFSA is absolutely essential to ensure that guidelines and laws are grounded in data. Still another crucial element of the EU system is the Rapid Alert System for Food and Feed (RASFF). It offers a real-time forum for member governments to exchange information about food safety incidents including fraud or contamination. Rapidly alerting all other nations, RASFF can start recalls and border checks should a risk be identified in one country. The foundation of this system is the General Food Law, which defines criteria for "farm to fork" concepts, risk assessment, and traceability. This regulation that defines particular roles for food industry operators and authorities helps one to realise that food safety is now an ongoing and shared responsibility all the way through the supply chain [11].

American customers turn to the Food and Drug Administration first for drug control. Food safety in the United States advanced dramatically in 2011 with the passage of the Food Safety Modernisation Act (FSMA). FSMA deviates from past reactive methods in that it emphasises prevention over response. It requires food producers, after identified potential hazards, apply preventative controls at every stage of production. Two further authorities given to the FDA under FSMA are third-party audits of imported food and ordering recalls. This was a great step forward since it brought the American food system into line with international norms and gave risk-based regulation first priority.

China, a country that generates and consumes more food than any other, has had major issues with food safety in the past few decades, including scandals erasing public confidence. The government so passed a new Food Safety Law with more strict control, higher fines, and clear obligations. One of its major changes is the central inspection system created by combining regulatory authority and lowering bureaucratic overlap [12]. Agencies can cooperate more successfully and consistently enforce the law when all the information is in one place. China has also stepped-up food testing, risk communication, and international cooperation to match its rules with global standards.

Lack of scientific and technical resources makes Codex Alimentarius standards a common basis for food safety laws used throughout Latin America and Africa. It is gratifying to observe that, especially in sectors connected to export-oriented agriculture, some countries in these areas have passed laws reflecting Codex recommendations. Capacity limits still create significant challenges, though. Among these issues include poor laboratory facilities, a dearth of appropriately qualified personnel, and slack enforcement policies. Development partners and international organisations like FAO and WHO have been very helpful in helping these communities create food safety systems, but nevertheless there are gaps especially in risk assessment, traceability, and surveillance.

Trade agreements heavily rely on harmonising food safety rules to try to close differences and promote homogeneity. Agreements between countries such as the Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organisation (WTO) exhord governments to base their own laws on Codex or ISO standards. With this harmonisation, which eliminates unnecessary trade restrictions, nations especially emerging ones are able to merge into global markets. Regional trade blocs as MERCOSUR, AfCFTA, and USMCA also want to harmonise food safety standards across members in order of consumer protection and simpler cross-border trade [13].

4. Core Elements of Food Safety Management Systems

Preventions, detection, and response the three pillars of food safety management systems are mutually linked. Operating on a national or even industry level, these systems aim at public health, consumer safety, and the security of the food supply chain. Laws, rules, scientific approaches, and public involvement are what make a system functional. Here are the foundations of successful food safety management systems found all throughout the world.

4.1. Food Legislation and Enforcement Structures

Any system guaranteeing food safety depends on a strong legislative basis. Food laws control production, labelling, import rules, and enforcement techniques as well as others. Government agencies, food industry owners and operators, and end users among other participants have to have their responsibilities clearly defined in these statutes. Laws are not the only thing that count; the execution of laws is also quite important. This includes recall of hazardous products, penalty for noncompliance, and an inspectorate with appropriate training. In countries with more developed institutions, enforcement is more proactive and data-driven; in settings with less resources, it is erratic. Still, rules and their execution help to promote food safety standards [13].

4.2. National Food Safety Policies and International Alignment

Regarding resource allocation and decision-making, national food safety programs serve as road maps. Apart from following global norms like ISO or Codex Alimentarius, these policies ought to reflect the particular needs, challenges, and resources of a nation. International alignment is absolutely vital in the growing global food market, as goods are routinely transferred across borders. Harmonising national laws with world standards helps nations increase market access and lower trade conflicts. Among nations with well-integrated policies combining local priorities with international obligations include Canada, Australia, and several of the EU members. Conversely, developing countries usually get technical help to align their systems by means of partnerships with agencies like the FAO, WHO, or WTO.

4.3. Scientific Risk Assessment and Risk-Based Decision Making

Fundamentally, modern food safety management depends on scientific risk assessment. Risk assessment helps avoid food safety problems from beginning by seeing likely hazards ahead of time and assessing their gravity and likelihood. This process consists in the following steps: spotting possible hazards, assessing exposure, classifying hazards, and so defining risks. This information helps authorities in charge of food safety make evidence-based decisions on maximum residue levels, additive approval, and target of inspection. Risk-based approaches ensure that funds are concentrated where they are most needed, not distributed thinly over all areas. This improves both the validity of rulings on food safety and efficiency of decision-making [14].

4.4. Capacity Building in Developing Countries

One of the main challenges to world food safety is the capability difference between nations with high and low incomes. Many developing nations deal with issues including limited laboratory infrastructure, outdated technologies, and inadequate trained personnel. These challenges limit their ability to monitor food safety concerns, follow policies, and participate in world trade. Because of its importance, global institutions such FAO, WHO, the Standards and Trade Development Facility (STDF), and bilateral donors often support capacity building. With expenditures in training, equipment, and institutional development, nations may build strong, self-sustaining food safety systems.

4.5. Food-Borne Disease Surveillance Systems

Surveillance systems tracking these diseases are absolutely vital if we are to offer early warning, respond to outbreaks, and stop food poisoning. These systems gather information from many sources including hospitals, labs, food corporations, and consumers to identify trends and new hazards. High-capacity countries use digital platforms and big data analytics to spot patterns and direct risk-based remedies. Some still depend on outmoded techniques of reporting and hand searches. Regardless of the structure, the aim of lowering disease by fast identification and resolution of issues at their source is the same. Through networks like the Global Foodborne Infections Network (GFN) and INFOSAN, administered by the World Health Organization (WHO), nations can exchange data and respond to transboundary dangers via global cooperation [15].

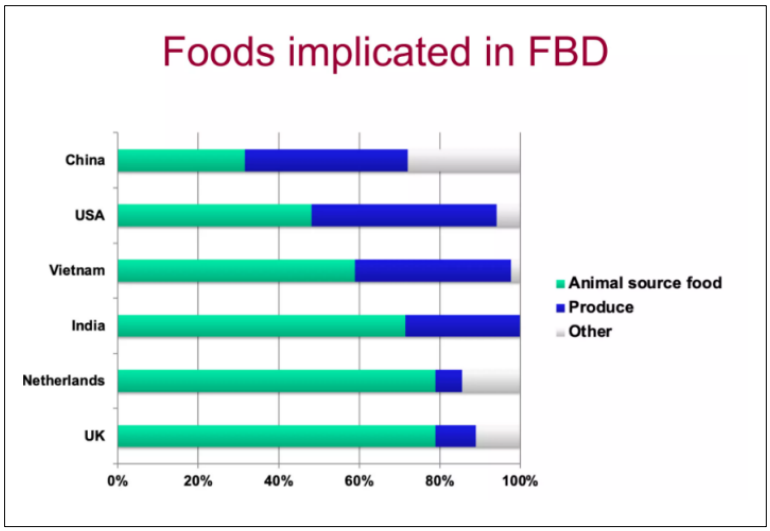

Figure 2 The chart shows the types of foods most frequently implicated in foodborne disease (FBD) outbreaks by country [17]

Good food safety practices rely on strong surveillance data. Comparative examination of six nations reveals that whereas produce is more important in Vietnam and China, most FBD cases in the UK, Netherlands, and India are associated to animal source diets as revealed by relative analysis. These patterns highlight the requirement of customised surveillance and risk reducing techniques matched with agricultural methods and country food profiles.

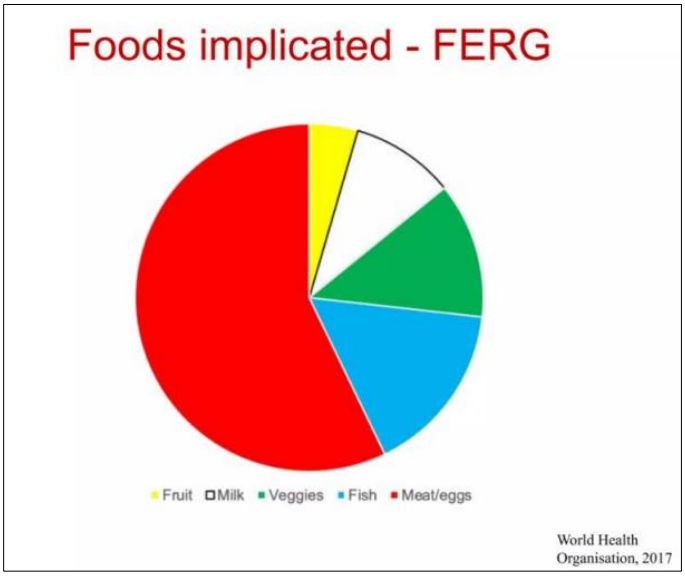

Figure 3 The chart shows the food implicated by FERG [18]

The Foodborne Disease Burden Epidemiology Reference Group (FERG) of the WHO claims that particular food categories contribute disproportionately to the worldwide FBD incidence and severity. The graphic guides focused food safety campaigns by showing how items including meat, dairy, and fruit are linked to the greatest disease burden.

5. Challenges to Global Food Safety

Ensuring the safety of food in a world with complex supply chains, diverse habitats, and shifting threats is no easy task. While food safety measures and international standards have made great advancement feasible, some pressing problems remain compromise the integrity of world food systems. These challenges include scientific, legal, environmental, and financial aspects in addition. Changing more responsive, powerful, and inclusive food safety rules requires on awareness of them [16].

5.1. Emerging Chemical and Biological Contaminants

In the present period, an increasing number of contaminants some of which are either not known or have limited knowledge cause a great threat to food safety. Globally especially concerning are microplastics and per- and polyfluoroalkyl substances (PFAS). Because they are used in food packaging, cookware, and agricultural products, the "forever chemicals," or PFAS, can gather in food and water supplies. Their persistence and potential to affect the immune system, hormones, and cancer make health organisations particularly focused on them. Furthermore unknown are long-term consequences of microplastics tiny bits of plastic on human health. Seafood, salt, even drinkable water all contain these pollutants. Science isn't keeping up with these evolving hazards, thus food safety systems must adapt quickly and include fresh approaches of testing, tracking, and controlling these molecules throughout supply chains [17].

5.2. Food Fraud and Adulteration: A Growing Concern

Particularly in world trade, food product adulteration and deliberate misrepresentation for financial gain are rising issues. Food sector adulteration compromises consumer trust in the system and can lead to major health issues including fake spices, mislabeled seafood, or diluted milk. Markets lacking border restrictions or monitoring can let counterfeit goods find their way in. These acts are difficult to expose because of their underhanded nature. Economic motivated food fraud damages honest food producers and dealers since it affects fair competition. Resolving this requires more cross-border collaboration in enforcement and information sharing as well as traceability system investments and whistleblower protection [19].

5.3. Antimicrobial Resistance and Zoonotic Foodborne Threats

Antimicrobial resistance (AMR) is a quiet but lethal epidemic driven on by the use of antibiotics in food-producing animals. Overuse of antibiotics in cattle can cause resistance in bacteria, which can cause more difficultly treatable human diseases. The food chain becomes a means of transmission as resistant bacteria travel from farms to consumers. Apart from AMR, zoonotic diseases those that spread from animals to humans raise continuous questions about food safety. Outbreaks of avian influenza or Salmonella highlight the need of integrated approaches such the One Health framework, which combines animal, human, and environmental health to prevent and control these hazards [20].

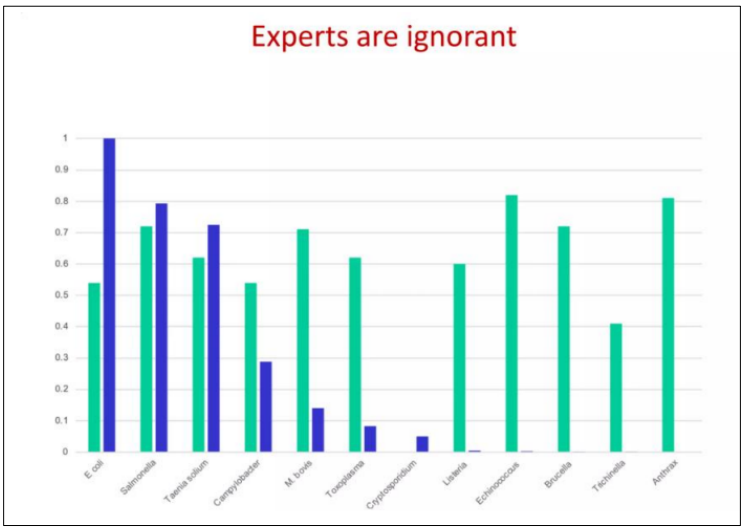

Figure 4 This chart highlights a knowledge or awareness gap between pathogens that experts emphasize (e.g., E. coli, Salmonella) and lesser-known but still significant threats (e.g., Anthrax, Brucella, Echinococcus) [20]

5.4. Climate Change and Its Impact on Food Systems

Climate change is affecting food production, storage, and transportation as well as food safety constantly growingly. More common in warmer climates, salmonella and listeria could find increasing frequency as average temperatures rise and alter weather patterns. A potent but sometimes invisible hazard, mycotoxins can be brought on by flood and droughs' water contamination, therefore promoting the growth of mould in crops. Changing surroundings may also force producers to employ new fertilisers and pesticides, which could produce residue in the food chain. If food safety systems are to be robust against these challenges, agribusiness and supply chain planners have to include risk assessments into their activities.

5.5. Trade Expansion and Fragmented Regulatory Compliance

Global food commerce has uncovered major flaws in regulatory coherence even while it has given economic advantages and better food access. Food often crosses several nations before it reaches the consumer, therefore weak links in the chain result from differences in food safety regulations, testing methods, and inspection capacity. Particularly in cases with technical ability or legal frameworks lacking, developing nations in particular struggle to meet the sometimes-strict criteria of importing nations. This fractured terrain demands more global alignment, capacity building, and trust-based alliances across borders and raises the possibility of dangerous products finding their way through the gaps [21].

6. Enforcement and Compliance Mechanisms

Ensuring food safety depends just as much on maintaining and following standards as on their setting. Enforcement and compliance actions are required to guarantee that food safety policies truly safeguard individuals in the actual world. We need strong inspection systems, smart technologies, and open regulatory frameworks to keep food safe from farm to table in today's ever complex global food supply chain.

Inspection systems are absolutely necessary to guarantee food safety. Globally, these policies range from simple, random inspections at food processing facilities to more sophisticated, risk-based plans aiming at sectors most likely to be harmed. Countries such the US, EU, and AU have strong inspection mechanisms in place with electronic monitoring systems, clear policies, and qualified workers under strong organisations. On the other hand, many low-income countries have limited resources, hence inspection frequency and coverage are also constrained; yet, paper-based approaches are nevertheless extensively applied in these countries.

With inspection levels depending on risk, a science-based approach is more prevalent in national frameworks. Under the EU's General Food Law, for example, inspections are conducted to fit the EU's integrated food safety network. Other international norms including Codex Alimentarius give countries instructions on how to enhance their own inspection systems. Particularly with imported foods that are subject to rules across many countries, international collaboration is absolutely vital [22].

Certification processes are crucial to guarantee that just safe foods are offered. Food companies can show they follow worldwide standards using G.A.P., ISO 22000, Hazard Analysis and Critical Control Points (HACCP). Trading usually requires these certifications, especially in profitable markets as the United States, Japan, and the European Union.

Regular internal and outside compliance audits help one to maintain accreditation. These audits help us to identify areas where our food safety protocols fall short and where we may improve. Multinational stores and suppliers also conduct internal audits to further ensure that dubious supply chain operations do not compromise their brands. As a tool to improve openness and enable cross-sector comparability, digitising audit data is becoming more and more important.

The fight for consumer confidence in safe food has benefited much from the development of effective techniques of tracking food. The source, processing technique, and safety of the food they eat pique the curiosity of consumers as well as government organisations. Standard barcoding systems are either complementing or perhaps being replaced by modern technologies such blockchain, which offers an unchangeable record of every step in the supply chain.

Blockchain technology integration lets manufacturers, distributors, regulators, and end users instantly exchange data. Should contamination arise, this enables authorities to rapidly identify the source of the affected batch, therefore mitigating damage and preventing possible outbreaks. Big companies such Walmart and IBM Food Trust have embraced blockchain technology to monitor the movement of perishable items including seafood and leafy greens.

Food safety incidents can occur independent of system design level of excellence. This emphasises how very important fast recall systems and global alert networks are. The Rapid Alert System for Food and Feed (RASFF) of the EU helps to quickly spread knowledge on possible hazards to human health. This strategy has helped to avoid several food poisoning outbreaks spanning national boundaries by means of fast recalls and public warnings.

More than 190 countries are able to share and transmit data on food safety issues through the International Food Safety Authorities Network (INFOSAN), which is jointly supervised by the World Health Organisation and the Food and Agriculture Organisation of the United Nations. These technologies that cut the time it takes to discover and respond help many lives to be saved as well as limit the cost effect. As more countries link to these networks and create their

own digital recall systems, general food safety resilience is getting increased. Faster responses worldwide are resulting from this [23].

Enforcement also depends critically on transparent, honest labelling and regulatory openness. Everyone is entitled to know the ingredients, cooking technique, and source of the food they purchase. Law now requires nutritional information, allergies, even QR codes for product traceability in several countries. While the European Union demands the clear labelling of genetically modified organisms (GMOs), U.S. fast food establishments openly display calorie numbers.

Apart from making businesses responsible, clear labelling guides consumers in making wise decisions. Regulatory authorities must regularly check and publically report if they are to enforce labelling rules. One end of the supply chain informs consumers, who then are more likely to demand better standards, therefore strengthening food safety culture.

7. Innovations and Digital Tools in Food Safety

Protective actions for the food supply of the planet will have to grow in line with the systems providing it. Developments in genetics, artificial intelligence, and digital platforms are rapidly changing our capacity to track, predict, and respond to hazards to food safety. Thanks to these technologies, global safety projects are today faster, more transparent, and more accurate.

7.1. Whole-Genome Sequencing in Outbreak Response

Whole-genome sequencing (WGS) is transforming authorities' tracking capacity for foodborne diseases. WGS allows researchers to find the precise genetic fingerprint of a pathogen, unlike other methods that merely find broad groups of bacteria. With this degree of accuracy, cases of sickness can be linked to certain food sources, processing facilities, or even vendors [24].

Countries like the United States that have included WGS into monitoring systems like PulseNet help to enable early identification of epidemics. For some farms infected during the romaine lettuce E. coli epidemic, WGS was used, for example. As more countries employ WGS, the global reaction to epidemics will be more exact and coordinated.

7.2. AI and Predictive Analytics for Risk Monitoring

In risk prediction and surveillance, artificial intelligence (AI) and machine learning are fast becoming indispensible. These technologies can sort through mounds of data including weather trends, trade routes, social media, and hospital reports to identify early on possible food safety concerns.

Predictive models help authorities manage resources and prioritise inspections. AI, for instance, may notify us to a rise in Salmonella cases in poultry imports from a specific area, therefore enabling us to intervene and examine more closely before the issue gets more severe. Real-time trend analysis made feasible by artificial intelligence allows food companies to proactively manage risks and stop costly recalls.

7.3. Blockchain and IoT for Real-Time Traceability

Blockchain plus the Internet of Things (IoT) is driving traceability right forward. Real-time monitoring of temperature, humidity, and freshness in packaging or storage facilities comes from sensors included in these spaces. Automatically uploaded to blockchain platforms, this data becomes part of an unchangeable record available to all interested parties [25].

This kind of openness fosters consumer confidence in addition to helping compliance. Imagine scanning a QR code on a milk carton to view its whole trip from farm to store shelf including milked, pasteurised, and transported times. These devices enable almost rapid reactions to any irregularities, lower fraud and avoid spoilage.

7.4. Open Data, Global Databases, and Real-Time Monitoring

Open-access food safety databases are encouraging worldwide information exchange and openness. Real-time data on outbreaks, recalls, and legislative changes is provided by sites including the Food Safety Platform of FAO, WHO's Global Surveillance System, and the Global Food Safety Initiative (GFSI). These databases enable evidence-based decision-making and let nations draw lessons from one another.

Open data helps civil society, journalists, and researchers to engage in food safety governance as well. Shared knowledge becomes a public good enhancing the worldwide capacity of the global community to guarantee safe food for all as food systems becoming more linked.

8. Sustainability and the Future of Global Food Safety

More than only public health depends on; food safety is a fundamental component of building a sustainable, equitable, and resilient planet. Rising populations, food instability, and climate change are among the urgent worldwide problems driving increasing awareness of the need of making sure food is safe for consumption. It ties environmental conservation and health with social and economic development. Food safety must be included with sustainability objectives and climate adaption if we are to guarantee a better planet and healthier people for next generations.

Strong framework connecting food safety with sustainability is offered by the Sustainable Development Goals (SDGs) of the United Nations. Key component of SDG 2 (Zero Hunger) is ensuring that healthy food is both safe and easily available. Reducing the prevalence of food-related diseases helps to fulfil the third Sustainable Development Goal, Good Health and Well-Being. Encouragement of responsible food handling, reduction of food waste, and enhancement of supply chain openness helps with SDG 12 (Responsible Consumption and Production). Efforts to guarantee food safety thereby help public health, economic security, and social justice as well as other aspects.

Climate change poses grave dangers to food safety. Given the rising count of new pests, erratic rainfall, and higher average temperatures endangering crop output and food storage, adaptive and climate-resilient food safety solutions are very vital. Growing crops resistant to high temperatures, improving cold-chain logistics, and developing water sanitation systems help to prevent contamination by means of these actions. Governments should also update existing monitoring systems to track climate-sensitive food-borne diseases and pollutants so that they may react fast to newly arising environmental hazards.

These systems cannot run effectively without strong infrastructure and adaptable laws. Future food safety will be decided by a mix of deliberate infrastructure investments and regulatory leeway. This entails ensuring logistical systems can handle shifting hazards, updating IT systems to enable digital traceability, and arming labs with modern tools. Regulatory authorities should, however, have the authority and flexibility to change food standards in view of new hazards rather than being limited by out-of-date laws or underfunded agencies.

Encouragement of food safety consciousness is just as crucial. Last but not least, changes that linger need public lobbying and education. Supported by the FAO and WHO, campaigns including World Food Safety Day observed annually on June 7 raise awareness of the need of safe food and inspire producers and consumers to contribute as well. These kinds of campaigns have the ability to influence behaviour, increase responsibility, and support policy changes. Public awareness of the problem is growing in line with the prospect of a safe, fair, sustainable, resilient world food system resistant to future hazards.

9. International Cooperation and Capacity Building

These days, food safety in our globally linked world depends on international cooperation entirely. Before it ends on the consumer's plate, food distances hundreds of miles. A single nation cannot be entirely responsible for guaranteeing the safety of food when international supply networks run through many countries. Working together, governments, international organisations, the business sector, and local communities can build reliable, safe, and strong food systems. On a worldwide basis, trust, cooperation, and mutual responsibility define the foundation of an effective food safety ecosystem.

Fundamental is the global organisations like the WHO, FAO, and WTO helping with standard harmonisation and emergency response. These groups move quickly in times of crisis like the melamine poisoning event of 2008 and continue to drive coordinated responses to epidemics and cross-border food hazards via platforms like INFOSAN and other food safety networks. The consistency these organisations create by setting scientific standards and harmonising food safety practices globally strengthens public health as well as international trade.

Ensuring food safety worldwide also involves supporting nations experiencing financial difficulty. Initiatives like the Standards and Trade Development Facility (STDF) and the FAO's e-learning programs are absolutely vital to cover the voids in capacity. Apart from helping countries to enhance infrastructure and participate in international standard-setting discussions, these programs educate legislators, food safety inspectors, and laboratory staff. Many countries

with limited resources depend on this help to strengthen their food control systems and get fair access to world markets so enhancing public health and economic development [23].

Still, institutional structures are not the only locus of international contact. Its success depends critically on cooperation among non-governmental organisations (NGOs), companies, and institutions. The commercial sector brings technology, logistical efficiency, and scale; non-governmental organisations (NGRs) provide essential community-level expertise and insights. Academics have research and innovative ideas grounded in evidence to improve models for food safety. Working across several domains enables the creation of scientifically based, easily implemented solutions for food safety, therefore benefiting all those engaged in the food chain.

Long-term gains in food safety depend on establishing a global standard of good government. This calls for the formulation of shared values of transparency, accountability, and openness among participants ranging in scope from small-scale farms and processors to major companies and government agencies. In a society of excellent governance, rules are not only followed but also embraced since they show a common commitment to protect human health, provide food fairness, and honour dignity. Advancement of this shared goal depends equally on partnerships, mutual respect, and global solidarity as on policy and research.

10. Conclusion

The security of the global food supply is a shared responsibility of the general public, infrastructure developers, industry stakeholders, food safety agencies, and legislators. Though strong international frameworks like those developed by Codex Alimentarius, ISO, and the World Health Organisation exist, the frequency of food-borne diseases especially in low- and middle-income countries persists everywhere. Key issues are emergence of new types of food contaminants, unequal application of safety criteria, and unequal access to safe food.

To address these issues, top authorities worldwide should advocate more consistent food safety rules grounded on codes and standards set by bodies such as Codex and ISO. Better world trade and simpler regulatory alignment would follow from this. Furthermore, highly needed are localised risk-based food safety rules, comprehensive surveillance systems, and better public education to minimise the long-term health consequences of harmful food.

Particularly in areas prone to food safety concerns, nations must give investments in modern digital traceability systems, state-of-the-art laboratory infrastructure top priority. Trained inspection staff is also very important. Including food safety into more general public health objectives including sanitation, nutrition, and disease prevention helps to maximise more efficient and effective use of public resources.

Maintaining consumer health from their food source finally requires constant cross-sector collaboration and coordinated worldwide effort. A strong and inclusive food safety system is important to guarantee public health as well as the prosperity of next generations.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have stated that they have no known competing financial interests OR non-financial interests OR personal ties that would have seemed to affect the work disclosed in this study.

Disclaimer (Artificial intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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