Asian Journal of
Biological Sciences

OPEN ACCESS

Food Security and Safety in Light of Global Megatrends: A Review

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ABSTRACT
Nearly all governments acknowledge food as a basic human need and as a component of human rights. Food goods are considered safe if they do not include any physical, biological or chemical hazards. It is seen as a crucial element of food security. Securing food safety to safeguard the general public's health poses a significant obstacle for both industrialized and developing nations. Due to the globalization of the food supply chain, multiple high-profile scandals and unscrupulous corporate practices, food safety has gained significant attention. By 2050, 9 billion people will need to be fed while depleting natural resources. Agriculture and food science's contribution to meeting the world's food needs with future food demand. Agriculture and the food system face increasing problems, particularly in crop and livestock production, as global megatrends and the threat of climate change worsen. A wide range of tactics and procedures are being investigated to reduce food loss and waste while also recovering lost commodities for use as novel raw materials in the food industry. A system-based approach to food security links efficient value, nutritious and healthful eating, crop production, food safety and supply networks in the face of global megatrends. The article advocates for a multidisciplinary and collaborative approach to food security science, with a focus on empowering approaches and upgrading technology in response to societal and global market developments, to achieve food security. Furthermore, this publication offers an overview of global food safety.

KEYWORDS
Agriculture, climate change, food security, food safety, food systems, global, megatrends

INTRODUCTION

Approximately 9 billion people will need to be fed via safe and sustainable food chains by the year 2050[1]. Food-related laws, standards, regulations, guidelines, education and guidance, particularly those concerning food safety, are continuously created or amended in the context in which the global food sector operates. Such developments can either coincide with or support rising food chain efficiency and effectiveness or they can add complication and confusion if they are not generally harmonized and consumers are not properly informed about food safety and nutritional problems. The expected doubling of global food demand and worldwide food trade in the coming decades is seen as the most major factor that will almost certainly induce an increase in food-borne disease[2].

ISSN: 1996-3351 (Print)
https://doi.org/10.3923/ajbs.2024.666.677

Received: 19-July. 2024
Accepted: 05-Sep. 2024
Published: 31-Dec. 2024

Climate change, the appearance of novel diseases and toxicants, an expanding population of at-risk (immunocompromised and aged) consumers and altering consumer preferences for fresh and minimally processed foods will all represent substantial challenges to global food safety.

Food safety regulations must be enforced and robust surveillance networks implemented at the national, regional and global levels. In addition, standardization and equivalence of regulatory systems will be crucial. The Centers for Disease Control and Prevention state that rather than a genuine rise in incidence, the recent increase in reported outbreaks and cases of foodborne illness is most likely the result of increased surveillance[3]. Alongside advances in the production and consumption of organic foods, there have been more foodborne illnesses linked to them in the United States in recent years[3]. Food safety communicators can better engage, inform and educate consumers about food safety hazards by using online communication platforms.

Further, keeping public health demands keeping food safe. Food safety must be addressed if food security is to be achieved. Food-exporting countries will face significant hurdles in the absence of food safety regulations. As a result, admission is dependent on meeting the food safety standards imposed by the global food business.

METHODOLOGY

The literature on food safety, food security, regulations, the food industry, global megatrends, climate change and food systems was searched for pertinent scientific content to develop this review study. The following databases were carefully searched: PubMed, Web of Science, Ebsco, Scopus and the Cochrane Controlled Register of Trials, as well as ProQuest and Google Scholar for grey literature. Electronic search strategies and the PICOS components of the current search approach (population, intervention, comparator, outcome and study design) are evaluated by peers Awulachew[4]. The english-language publications that were released between January, 2007 and December, 2023 were considered. Similarly, extra relevant data was found by searching references to the obtained documents.

FOOD SAFETY

Concept of food safety: The notion that food shouldn’t cause harm to customers is the cornerstone of food safety. Stated differently, food safety ensures that a customer won’t become sick after eating. Food safety is crucial for both nutrition and food security. It is also a crucial component of public health. As part of the effort to reduce hunger, it is recognized[5].

The concept of food safety is difficult. It is an interdisciplinary field of research that provides food safety protocols for handling, storing and cooking food. Food-borne infections, contaminated food, residues and pollutants, chemicals and preservatives and high-sugar and high-fat diets are some of the most serious food safety concerns. Contaminated food can make people sick and cause both acute and chronic illnesses. Food hazards can cause food losses and a decrease in available food. Controls for food safety are critical for preventing, removing or eradicating microorganisms in food. Despite efforts by food firms and government groups to ensure food safety, some food products include viruses, fungi, bacteria and parasites.

Customers’ top concern is food safety and it is necessary to build their trust. Nations now have to regulate food safety due to increased political and economic pressure for stronger precautions against foodborne illness. A scientifically grounded food safety system, such as Hazard Analysis and Critical Control Points (HACCP), has been shown to lessen but not eliminate the likelihood of food safety incidents. Food processing companies created the HACCP system, which covers the entire food production process from farm to fork, to guarantee safe food production[6].

Benefits and drawbacks: Food safety is a real and relevant concern. It is closely related to the problem of food control[7]. Enhancing food safety is a crucial first step in achieving food security. Global food networks that connect disparate human groups open up new opportunities for food diversity and economic prosperity. The importance of food safety to our health cannot be overstated. Two common benefits of improved food safety are a reduction in missed production and a life free of foodborne illness. Global food safety is a prerequisite for global food security. Global food trade is supported by international food safety standards and enforcement, which improves living conditions and the economy.

Food safety problems were frequently eclipsed in the past by domestic factors including earthquakes, floods, droughts and political unrest. A few obstacles to guaranteeing the safety of imported foods are the growing intricacy of the world's food supply networks and the rise in imports from developing nations. Because of the intricate global food supply networks, traceability can provide significant challenges even though it is crucial for ensuring food safety. Food safety is difficult to control since it is difficult to identify. Food transportation across national boundaries may be impeded by disparities in food safety legislation[6]. Since it might be difficult to recognize nanoparticles in imported commodities, worldwide collaboration is needed to guarantee nano-safety. Global food safety depends on standards and legislation being harmonized. Some countries have laxer laws governing food safety.

FOOD AND GLOBAL MEGATRENDS

Global food security: To meet the increased demand for food caused by the world's growing human population, industrial-scale and centralized production systems, such as large-scale farming, intensified animal production and large-scale food processing and distribution, have expanded dramatically over the last few decades. The growing proportion of imports from less developed countries raises serious food safety concerns. Many underdeveloped countries use fecal-contaminated irrigation water for fruit and vegetable cultivation, as well as untreated chicken manure and human feces in aquaculture[8].

Climate change: The climate change is a current worldwide issue. Climate change may worsen as the food supply becomes more globalized, resulting in increasing greenhouse gas emissions from increased production and transportation. While the degree of its effects is still debated and overall, weather conditions have become more unpredictable, with extreme weather events becoming more frequent and intense[9].

Local climatic conditions influence local vegetation and when the climate changes, growth seasons may alter, resulting in biological effects such as differences in crops grown and animals farmed[9]. This could result in changes in plant and animal epidemiology, as well as ecosystem modification. Climate change is predicted to alter several areas of food safety and security, including the predominance of rotting organisms, changes in existing plant and animal pathogen epidemiology and the migration, introduction and invasion of novel pests and diseases[10].

To mitigate the effects of climate change, political, technical and investment support, as well as incentives, will be required to assist in the development of diversified and resilient land use systems to feed the growing population. Similarly, more multidisciplinary study is required to improve our understanding of the ecological systems underlying, say, seafood security and safety concerns.

Growing aging population: Foodborne disease is known to impact vulnerable populations, notably the elderly, more severely. With a rapidly aging population and an increasing number of immunocompromised people, the negative effects of epidemics are anticipated to become more serious from a public health standpoint. This is especially concerning given contemporary consumer and store efforts to make foods with no preservatives, lower salt concentrations, closer to neutral pH and acceptable for ambient storage[5]. One potential solution to this conundrum is the development of "extra safe" food items, such as irradiated, sterilized or pasteurized foods, aimed toward higher-risk populations[8].

Food manufacturers and marketers will need to be more conscious that a population with heightened sensitivity is eating their products, pay closer attention to how they assess food shelf life and develop meals with built-in barriers.

Digital food and the internet of food: The Internet purchase of food is likely to grow with increases in urbanization especially in countries like China where a relatively higher percentage of the population already purchase goods over the Internet. This could improve food safety by enabling food companies with robust food safety systems to have greater reach, but have the opposite effect if systems suffer transportation failures with foods not being held at the right temperatures or other breakdowns or inadequacies. What is clear is that Internet-based purchases of food will need to be audited to the same standard as ‘bricks and mortar’-based systems.

Rising demand for personalized foods, diets, services and experience: To fulfill the shifting expectations of consumers, the food business must focus on innovation. These criteria include developing food products that are simple to make, healthy, highly sensory and suited to each individual’s dietary needs. The demand for seasonal, locally farmed organic, and/or sustainable food items is rising as ethical consumerism grows. The food sector is experiencing an expanding dilemma as consumers’ “want it all” attitudes rise. Collaboration across science, medicine, gastronomy and industry is more important than ever as a result of this demand. Personalized diets are more concerned with nutritional elements than with food safety; for example, using different types of microbiomes to treat specific diseases may cause unintentional food safety issues by altering the gut microflora in unanticipated ways. A purely empirical approach could be risky, so more systematic study is required, including the use of nutrigenomics, metabolomics and toxicogenomics. The introduction of new, less traditional food preservation technologies will necessitate safety being included in and based on risk management principles.

EMERGING FOOD SAFETY ISSUES

Antibiotic resistance: The number of antibiotic-resistant bacteria causing serious and life-threatening diseases is rapidly increasing. The quick transmission of resistance genes between bacteria, paired with an increasingly connected globe, increases the global spread of resistant strains[11]. The possibility that antimicrobial resistant cattle pathogens will pass their resistance on to human pathogens raises serious concerns about treating human diseases with antibiotics that may already be useless. Due to the increasing problem of antibiotic resistance and the scarcity of new antibacterial medications, a variety of alternate techniques have been proposed[12]. However no ‘magic bullet’ replacement exists. To ensure that antibiotic resistance does not jeopardize food security and seriously damage human disease control, scientists and business must encourage innovation and research into new measures and solutions to prevent the emergence and spread of antibacterial resistance.

Enteric viruses, specifically norovirus (NoV) and hepatitis A virus (HAV), play an important role in foodborne illness. Viruses thrive in the environment and are far more resistant to certain storage conditions than bacteria[13]. It is therefore vital that a better understanding of how a combination of technologies might be used to inactivate foodborne viruses.

Virally infected food and water typically have no organoleptic consequences. The ability to detect viral particles, which are typically found in low concentrations in contaminated food, is further hindered by the lack of universal or rapid culture-based methods for producing foodborne viruses. In the absence of culture procedures, standardized methodologies for molecular detection of foodborne viruses, particularly NoV and HAV[14], are required.

Chemical risks can contaminate the food supply chain at any point, persist and accumulate in animals and people. They can also reach larger concentrations in organisms' tissues. However, acute health impacts are infrequent and it is well known that the biggest influence on human health occurs with low-level repeated exposure. This makes determining a link between exposure and sickness extremely difficult, although there is growing worry that chemical exposure may play an important role in the etiology of many disorders.

Economically motivated adulteration of food: Food adulteration for economic gain is a long-standing global phenomenon[15]. Because of the inherent financial motivations, many economically driven adulteration instances focus solely on high-value food products/commodities. Food commodities with lengthy and/or complex supply chains are likewise more susceptible to economically motivated adulteration[16]. According to the Economically Motivated Adulteration Incidents Database, fish and seafood are the most heavily impacted food categories, followed by dairy products and oils and fats[17]. In contrast to incidental contamination, economically motivated adulteration is generally more difficult to detect and confirm because the motive is always to avoid discovery and adulterants are frequently used that are highly comparable to the product being adulterated.

Although, non-toxic adulterants are frequently employed, economically driven adulteration episodes can have serious consequences for health. The FDA Food Safety Modernization Act includes a final regulation targeted at avoiding intentional adulteration as a result of acts designed to cause widespread harm to public health, such as terrorism targeting the food supply[17]. However, a global whole-of-system strategy with multidisciplinary input from scientists (e.g., testing methodologies), regulators (e.g., legislative frameworks) and industry (e.g., supply chain simplification) will be necessary.

Allergens and intolerances: Food allergies affect between 3.5 and 4.0% of the global population and are on the rise in both industrialized and developing countries[17]. The complexity of protecting food-allergic consumers stems from the fact that, unlike bacterial or viral contamination, which affects everyone, the presence of allergens only affects a vulnerable segment of the population and the consequences of consumption could be fatal. Most industrialized nations require labeling of the most prevalent allergenic foods, as well as substances derived from such foods, by the 1999 Codex Alimentarius (Codex) standards[18]. However, more than 170 foods have been recognized as possibly allergic and novel food sources are currently being investigated to address the future food insecurity issue[18]. Variances in dietary habits between countries can also result in variances in allergenicity to specific foods. A system for categorizing and prioritizing allergenic foods based on public health value has recently been developed, with the expectation that regulators will adopt it[18].

Nanotechnology: Although, research and development on nanotechnology is still in its infancy, it has the potential to permeate every facet of food production. The food sector has primarily used engineered nanoparticles (ENPs) in the development of innovative food packaging materials, with several commercial items already on the market[17]. However, it is challenging to estimate the total amount of nanotechnology used globally due to a lack of defined laws and standardization in this field.

Genome editing: Some of the current uses of genome editing have enormous potential to affect the security of the global food supply. Transcription activator-like effector nucleases (TALENs) and clustered regularly interspaced short palindromic repeat (CRISPR)/Cas systems (e.g., Cas9) are two examples of genome editing technologies that allow targeted modification of specific DNA sequences at their normal chromosomal locations. Changes can range from a single base pair to a large deletion in size[17,19].

It's currently unknown how or whether this emerging technology will be regulated in the majority of the world[20]. In addition to potentially hindering innovation and making already complex international trade difficulties worse, this lack of uniformity also runs the danger of eroding consumer confidence in the safety of biotechnology products and the risk assessment procedure[20]. There is unquestionably a need for public education campaigns on the risks associated with whole genome editing.

CURRENT GLOBAL REGULATORY ENVIRONMENT, ADVANCES IN FOOD SAFETY AND TECHNOLOGY

Current global regulatory environment: As a result of the globalization of the food supply chains, robust through-chain traceability laws are being implemented in many nations. These laws aim to protect food chains and detect safety breaches in their integrity.

A one-step forward, one-step back strategy is outlined in the CAC guidelines; that is, the previous source from which the food or ingredient was bought or purchased and the subsequent location in the supply chain. Regulation EC No. 178/2002 of the EU and numerous other authorities, such as the US Food and Drug Administration (CFR Title 21) and Food Safety Australia New Zealand (Standard 3.2.2) have both implemented this regulation[17]. However, this method can be lengthy and laborious and in the event of a breakdown or crisis in food safety, the consequences could be dire. Industry participants may take a more transparent approach to the supply chain by going back and forth more than one stage in order to enable a quicker reaction.

Private food safety standards are generally established by private corporations and standard-setting coalitions, which contractually require their suppliers to comply with their standards. Private food safety standards are increasingly monitored and enforced through third-party certification and they might apply to product qualities as well as process and manufacturing processes. The primary drivers of the expansion of these private food safety schemes have been the unambiguous attribution of legal responsibility to food chain operators for guaranteeing food safety; increasingly global and complicated supply chains; and rising consumer awareness of food, health and food safety. Furthermore, private standards-setting bodies can respond considerably faster than Codex to emerging challenges and produce new or revised standards.

In general, unless private standards truly outperform current public standards, their adoption shouldn't be promoted. Big retailers need to collaborate with groups like the Food and Agriculture Organization, the World Organization for Animal Health and Codex in order to demonstrate the advantages of the requirements they are placing on their suppliers. Organizations like Codex, the Global Harmonization Initiative and the GFSI need to better coordinate and align with one another.

ADVANCES IN FOOD SAFETY AND TECHNOLOGY

Whole-genome sequencing: The whole-genome sequencing is the simultaneous determination of an organism's whole DNA sequence. The WGS technology has the ability to significantly improve food safety and security. The global use of whole-genome sequencing technology in the food, veterinary and human health sectors would facilitate sharing and collaboration while also significantly increasing the availability of contextual data when interpreting results and recommending scientifically sound regulatory actions.

The industry can also use the genomic information that whole-genome sequencing provides as a tool to monitor the supply of ingredients, evaluate the efficacy of sanitary and preventive controls, develop new, quick methods and tests that do not require culture and detect a wide range of pathogens-not just bacteria-in a single test. It can also be used to control and determine how long pathogens persist in the environment, monitor newly emerging pathogens and potentially identify antimicrobial resistance. Furthermore, the public needs to be informed that the food safety system is probably still in place and that whole-genome sequencing technologies are making an expanded surveillance system possible.

Metagenomics: The examination of genomes present in an environmental sample without regard to culture is known as metagenomics. By using metagenomic methods, we can improve our comprehension of the intricate, varied and ever-changing microbial populations found in food and surroundings related to food. Metabolism investigations have been greatly aided by next-generation sequencing's capacity to provide vast volumes of DNA sequence data. Metagenomics research can also benefit from the development of broad-range 16S rDNA PCR tests that target highly conserved nucleotide regions shared by all bacterial species[21]. One of the most exciting applications of metagenomics is the ability to locate and identify hitherto unknown pathogens in food matrices and food-associated environments. According to CDC estimates, unidentified agents are responsible for almost 80% of foodborne disease cases in the United States[17]. This suggests that to close the current knowledge gap regarding unidentified and unknown food-borne agents, a more effective foodborne disease surveillance system is needed [22]. It is unclear how the food sector and authorities will respond to these new results, particularly given the numerous obstacles that still need to be overcome before metagenomics techniques can be used to identify foodborne infections.

Transcriptomics and proteomics: Determining the physiological condition of pathogens on foods and in the food production environment is necessary in order to design logical control methods for foodborne pathogens in the food supply[17]. Studies utilizing transcriptome and/or proteome analysis have been conducted to examine the reactions of diverse foodborne pathogens throughout their adaption and growth on particular food matrices[23]. Additionally, mechanistic insights into the mechanisms underlying microorganisms' responses to distinct food processing interventions have been obtained[17]. This data can provide insight into the mechanical mechanisms underlying obstacle technology synergy. Furthermore, biomarkers associated with particular resistance traits of a pathogen can be found and included into mathematical models to forecast microbial behavior, thereby enhancing management strategies.

Insights from these studies may also pave the way for the development of better detection methods (for example, methods targeting highly expressed RNA molecules) as well as improved risk assessments that take into account the fact that a pathogen's virulence can be significantly affected by its physiological state[23]. As a result, businesses and food regulatory agencies will be charged with determining how to effectively use the data provided to modify their own processing and preservation methods.

Assessments of chemical risks and safety: The safety assessment of food ingredients and/or contaminants must consider not only the possible threat posed by a single compound, but also the consumer's amount of exposure. A food hazard is defined as a biological, chemical or physical agent present in food that has the potential to cause harm to one's health. The phrase also refers to an inherent quality of an agent or circumstance that has the potential to produce negative consequences. In contrast, risk reflects the likelihood and extent of an undesirable outcome in an exposed system or (sub) population[24]. In emergency situations where fast assessments of potential health concerns are necessary, a hazard-based approach can be useful.

Hazard-based techniques may also apply to compounds that have potent non-threshold effects, such as certain severe genotoxic carcinogens. A hazard-based element is also inherent in the so-called threshold of toxicological concern concept, which gives a general approach to the safety assessment of compounds with no or insufficient toxicological data[17]. The approach gives guidelines for determining acceptable risks by identifying toxicologically negligible exposures based on hazard and chemical structure. In general, risk-based approaches to food safety assessments are appropriate, as long as they are based on valid exposure estimates and account for uncertainty in exposure assessment. Equally important is the clarification and suitable consideration of the mode of action, which must be placed in context with an accurate estimate of consumer exposure.

Advances in chemical analytical testing: The capacity to correctly quantify the concentration of a specific contaminant in a food matrix is crucial for assessing the risk to consumers. As a result, novel analytical methodologies are constantly being developed in response to the ever-increasing number of contaminants already present in food or emergent dangers that threaten to infiltrate the food supply chain. The primary goal of many analytical techniques is to increase sensitivity for difficult-to-detect pollutants while reducing cost and analysis time per sample. Advances in mass spectrometry have resulted in an enhanced ability to properly determine, quantitatively and qualitatively, a large number of analytes with varied physicochemical properties at the same time[25]. The 'dilute-and-shoot' quantitative multi-residue assays that target hundreds of analytes in a single run with minimum sample preparation are becoming the rule rather than the exception[17]. While advances in analytical specificity and sensitivity have made it possible to identify only a few molecules in a given environmental matrix, this alone does not provide reliable exposure assessment. In addition to valid metrics for the amount of an agent included in food or other consumer items, its bioavailability from the matrix, as well as the length, amplitude and frequency of exposure, are critical components of risk assessment knowledge.

Advances in chemical hazard characterization: The ongoing progress in genomics, transcriptomics, proteomics and metabolomics, combined with novel tools in bioinformatics and system biology, has resulted in promising new avenues for improved toxic hazards characterization, which is expected to be further developed in the coming years. While entire animal toxicity studies continue to be the cornerstone of existing regulatory regimes, concerns about animal welfare, high costs and the capacity to properly predict *in-vivo* tissue functions in humans have fueled interest in alternate methods. Current alternative methodologies in development include microfluidic organs-on-chips, 'omics' techniques (e.g., transcriptome fingerprinting of suitable cell cultures) and computational estimating methods for predicting acute and chronic systemic toxicity[17].

The identification of appropriate biomarkers in human/animal biological fluids (e.g., serum, plasma, urine, breast milk and others) or tissue biopsies has also resulted in more accurate population exposure estimates to hazardous pollutants. To focus on specific metabolites as quantitative exposure indicators, comprehensive knowledge of the relevant compound's metabolism is required[24]. A large database of human exposure estimates for the genotoxic carcinogen acrylamide, based in part on biomarkers of exposure [17], serves as an example.

Understanding the significant background of DNA damage in human tissues, which is consistently induced by endogenous genotoxic agents produced during normal metabolism, allows future risk assessments of genotoxic agent exposure to evaluate the incremental contribution of a given exogenous exposure to endogenous background DNA damage. This will provide a data-driven approach to risk assessment (bottom-up), as opposed to mathematical extrapolation spanning multiple orders of magnitude, from the dose range accessible through animal trials to consumer exposure (top-down)[17].

Processing and packaging: The main technique for pasteurizing and sterilizing food is thermal processing. Heat, however, degrades the quality of food. Consumer demands for minimally processed, pathogen-free products present a constant challenge for food makers in the context of a global food industry with increasingly extended supply networks. Innovative non- or mildly-thermal methods present fresh opportunities for creativity in response to consumer demands[26]. Consequently, there is a risk that the effects of food-borne illnesses on the economy may increase unless interventions can reduce the incidence of these illnesses. This emphasizes the need to develop and implement novel food processing and preservation methods to improve food safety throughout the food chain. As regulatory agencies move towards outcome-based regulations, it will become increasingly necessary for the food industry to have a variety of inactivation technologies at their disposal.

The food-packaging industry has also been challenged with respect to maintaining safety and quality, as traditional passive-barrier packaging systems have reached their limit with regard to further shelf-life extension of packaged food. To provide such extension and to improve the quality, safety and integrity of packaged food, innovative active and smart packaging concepts have been developed.

Big data: The globalization of our food supply networks complicates the response to outbreaks of foodborne illness. Global food safety, food quality and sustainability could all improve significantly if the food industry adopts a big data culture[17]. Big data refers to information assets with large volume, high velocity, high veracity and/or high variety that call for novel processing techniques to improve decision-making, uncover new insights and optimize processes. The majority of big data analytics and huge dataset applications in food safety and quality to date have concentrated on improving root causes and retrospective analyses; however, the use and development of predictive analytics in food safety is anticipated to surge in the near future[17]. Integration of diverse data sources may not only allow for improved and accelerated root cause analysis but this information could be used to adjust food safety and operational practices in near real-time to include additional barriers and controls.

Geographic information system: The spatial and temporal prevalence of food-borne pathogen contamination in produce production systems has also been predicted and managed using GIS-based datasets[17]. The industry must move now to position itself to benefit from big-data tools and solutions for challenges related to food safety and quality. Among the most significant issues facing the food business will be data integration and ownership. Producers, retailers, health authorities and regulators will need to share the results of big data processing.

Meta-analyses, systematic reviews and predictive microbiology: Understanding how bacteria develop in response to environmental stimuli and condensing that information into mathematical models or equations is the basis of predictive microbiology[17]. In the food industry, predictive microbiology has proven to be extremely useful. It can support quantitative risk assessment and decision-making during Hazard Analysis for Critical Control Point (HACCP) planning, food shelf-life estimation and product design or reformulation. For example, predictive microbiology is extremely valuable to the government and industry when it comes to Listeria challenge trials and figuring out whether new food compositions promote or hinder the spread of the disease. A determination of the kinetics of heat inactivation of an organism of interest inside a particular food product might also be beneficial to industry. Even with the large number of models that have been created and published, validation still requires independent, business-based trials.

With the creation of open, community-driven, web-based predictive microbiological model libraries, the application of predictive microbiology knowledge to real-world food processing applications will only increase. Systematic reviews are becoming more and more used in different areas of food safety[17,27]. The creation of through-chain risk management techniques will gain from a deeper comprehension of supply chain risks. The question of how this information will be used, if new regulatory requirements will be imposed and the ensuing implications for the food sector remain even with an increased understanding of food safety hazards and intervention options.

Tools for tracing supplier chains: Foodborne sickness and plant or animal diseases are becoming more common and this has increased the requirement to be able to trace impacted products both domestically and globally. To promptly pinpoint the possible outbreak's origin, it is crucial to trace it back to the early phases of an epidemic. A review of the global food traceability regulations in major OECD countries revealed that none of the countries had an electronic tracking system for all commodities, highlighting the need for more sophisticated traceability systems for other domestic and imported products[18]. Many developed countries have implemented new legal requirements for traceability and exporting countries are under pressure to comply with the regulations set up by importing countries[28].

Self-interested parties must be encouraged to commit since, despite technology developments, the design, implementation and upkeep of a traceability system are frequently decentralized. In the food industry, there are new traceability trends aimed at streamlining operations[17]. But as was already mentioned, the main obstacle to implementing these solutions is cost. Consumer enthusiasm for these items may drive away some smaller companies who lack the resources to implement traceability systems as they become increasingly common. Comparably, changes in traceability regulations may result in the exclusion of certain producers from the market.

Conventional and social media: In addition to making foodborne illnesses more easily transported and disseminated, globalization has also made news more easily disseminated through media outlets like TV and the internet, which has negatively impacted companies' bottom lines. According to numerous reports, the media exaggerates and distorts the risk associated with food accidents, which erodes public confidence in the food supply[29]. Food-related issues may not be thoroughly explored before publishing or transmission and the level of risk posed may be overstated as a result of the rush to publish and the tactics used to construct a "newsworthy" story[17,29]. As a result, the media may be a bad source of information on food risks and may also increase public worry about food risks[17].

Researching this subject offers a great opportunity because it's arguably one of the most important parts of building a strong environment for food safety. Gaining public support and facilitating the adoption of techniques and technologies that improve our capacity to provide global food security may also be accomplished through accurate and transparent communication regarding the use of particular agricultural practices or food processing technologies that have the potential to cause social unrest. To generate conversation and enlighten the public and media, food safety experts must take the initiative to establish and manage social media accounts as well as other channels for the targeted distribution of food safety information.

CONCLUSION

Food safety is essential for maintaining public health and ensuring food security. Food availability has been and will continue to be crucial to the advancement of human society. In actuality, societal advancement may be considered contingent upon food security. Strongly encourage the harmonization and equating of regulatory and standard frameworks. Future food-related concerns will require a flexible and responsive strategy.

SIGNIFICANCE STATEMENT

The article advocates for a multidisciplinary and collaborative approach to food security science, with a focus on empowering approaches and upgrading technology in response to societal and global market developments, to achieve food security. Furthermore, this publication offers an overview of global food safety. A wide range of tactics and procedures are being investigated to reduce food loss and waste while also recovering lost commodities for use as novel raw materials in the food industry. The study's findings showed that the international food community must come up with creative solutions to get beyond these obstacles. To effectively handle the food concerns of the future, a responsive and adaptable strategy will be required.

REFERENCES

1. Godfray, H.C.J., J.R. Beddington, I.R. Crute, L. Haddad and D. Lawrence *et al*., 2010. Food security: The challenge of feeding 9 billion people. Science, 327: 812-818.
2. Quested, T.E., P.E. Cook, L.G.M. Gorris and M.B. Cole, 2010. Trends in technology, trade and consumption likely to impact on microbial food safety. Int. J. Food Microbiol., 139: S29-S42.
3. Harvey, R.R., C.M. Zakhour and L.H. Gould, 2016. Foodborne disease outbreaks associated with organic foods in the United States. J. Food Prot., 79: 1953-1958.

4. Awulachew, M.T., 2024. Engineering principles and business model innovation in food systems to achieve sustainable development goals. Asian Sci. Bull., 2: 229-241.
5. Awulachew, M.T., 2021. Food product shelf stability overview of sourdough-risen flatbread. J. Food Technol. Nutr. Sci., Vol. 3. 10.47363/jftns/2021(3)123.
6. Sadiku, M.N.O., T.J. Ashaolu and S.M. Musa, 2019. Food science: A primer. Int. J. Trend Sci. Res. Dev., 3: 839-841.
7. Uyttendaele, M., E. Franz and O. Schlüter, 2016. Food safety, a global challenge. Int. J. Environ. Res. Public Health, Vol. 13. 10.3390/ijerph13010067.
8. Doyle, M.P., M.C. Erickson, W. Alali, J. Cannon and X. Deng *et al*., 2015. The food industry's current and future role in preventing microbial foodborne illness within the United States. Clin. Infect. Dis., 61: 252-259.
9. Stewart, L.D. and C.T. Elliott, 2015. The impact of climate change on existing and emerging microbial threats across the food chain: An island of Ireland perspective. Trends Food Sci. Technol., 44: 11-20.
10. Vezzulli, L., C. Grande, P.C. Reid, P. Hélaouët and M. Edwards *et al*., 2016. Climate influence on *Vibrio* and associated human diseases during the past half-century in the coastal North Atlantic. Proc. Natl. Acad. Sci. U.S.A., 113: E5062-E5071.
11. Holmes, A.H., L.S.P. Moore, A. Sundsfjord, M. Steinbakk and S. Regmi *et al*., 2016. Understanding the mechanisms and drivers of antimicrobial resistance. Lancet, 387: 176-187.
12. Cheng, G., H. Hao, S. Xie, X. Wang, M. Dai, L. Huang and Z. Yuan, 2014. Antibiotic alternatives: The substitution of antibiotics in animal husbandry? Front. Microbiol., Vol. 5. 10.3389/fmicb.2014.00217.
13. de Keuckelaere, A., D. Li, B. Deliens, A. Stals and M. Uyttendaele, 2015. Batch testing for noroviruses in frozen raspberries. Int. J. Food Microbiol., 192: 43-50.
14. Stals, A., L. Baert, E. van Coillie and M. Uyttendaele, 2012. Extraction of food-borne viruses from food samples: A review. Int. J. Food Microbiol., 153: 1-9.
15. Long, L.M., 2009. Swindled: The dark history of food fraud, from poisoned candy to counterfeit coffee by Bee Wilson. J. Am. Cult., 32: 283-284.
16. Kennedy, S., 2008. Why can't we test our way to absolute food safety? Science, 322: 1641-1643.
17. King, T., M. Cole, J.M. Farber, G. Eisenbrand, D. Zabaras, E.M. Fox and J.P. Hill, 2017. Food safety for food security: Relationship between global megatrends and developments in food safety. Trends Food Sci. Technol., 68: 160-175.
18. Houben, G., P. Burney, C.H. Chan, R. Crevel and A. Dubois *et al*., 2016. Prioritisation of allergenic foods with respect to public health relevance: Report from an ILSI Europe food allergy task force expert group. Food Chem. Toxicol., 89: 8-18.
19. Carroll, D. and R.A. Charo, 2015. The societal opportunities and challenges of genome editing. Genome Biol., Vol. 16. 10.1186/s13059-015-0812-0.
20. Jones, H.D., 2015. Future of breeding by genome editing is in the hands of regulators. GM Crops Food, 6: 223-232.
21. Oikonomou, G., V.S. Machado, C. Santisteban, Y.H. Schukken and R.C. Bicalho, 2012. Microbial diversity of bovine mastitic milk as described by pyrosequencing of metagenomic 16s rDNA. PLoS ONE, Vol. 7. 10.1371/journal.pone.0047671.
22. Aw, T.G., S. Wengert and J.B. Rose, 2016. Metagenomic analysis of viruses associated with field-grown and retail lettuce identifies human and animal viruses. Int. J. Food Microbiol., 223: 50-56.
23. Tang, S., R.H. Orsi, H.C. den Bakker, M. Wiedmann, K.J. Boor and T.M. Bergholz, 2015. Transcriptomic analysis of the adaptation of *Listeria monocytogenes* to growth on vacuum-packed cold smoked salmon. Appl. Environ. Microbiol., 81: 6812-6824.
24. Eisenbrand, G., 2015. Current issues and perspectives in food safety and risk assessment. Hum. Exp. Toxicol., 34: 1286-1290.

25. Hird, S.J., B.P.Y. Lau, R. Schuhmacher and R. Krska, 2014. Liquid chromatography-mass spectrometry for the determination of chemical contaminants in food. TrAC, Trends Anal. Chem., 59: 59-72.
26. Turantaş, F., G.B. Kılıç and B. Kılıç, 2015. Ultrasound in the meat industry: General applications and decontamination efficiency. Int. J. Food Microbiol., 198: 59-69.
27. Aiassa, E., J.P.T. Higgins, G.K. Frampton, M. Greiner and A. Afonso *et al*., 2015. Applicability and feasibility of systematic review for performing evidence-based risk assessment in food and feed safety. Crit. Rev. Food Sci. Nutr., 55: 1026-1034.
28. Charlebois, S., B. Sterling, S. Haratifar and S.K. Naing, 2014. Comparison of global food traceability regulations and requirements. Compr. Rev. Food Sci. Food Saf., 13: 1104-1123.
29. Henderson, J., A. Wilson, S.B. Meyer, J. Coveney and M. Calnan *et al*., 2014. The role of the media in construction and presentation of food risks. Health Risk Soc., 16: 615-630.