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Food Safety in the 21st Century: A Review

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ABSTRACT

Since food is necessary for survival, food safety is a fundamental human right. Unsafe food puts billions of people around the globe at risk. Every year, millions of people get sick, and many pass away. Microbial, chemical, personal, and environmental hygiene issues are present throughout the food chain, which extends from farm to fork or plate. In the past, deliberate or unintentional individual behavior and state failure to protect food quality and safety have resulted in documented human tragedies and economic disasters related to eating tainted food. Recent outbreaks have been caused by microbiological organisms, while early instances were mostly chemical pollutants. Children under the age of five, the elderly, and the ill suffer the most from the Disability Adjusted Life Years (DALYs) attributable to these agents. Rapid and precise pathogenic agent identification is crucial for ensuring food safety and against unnecessarily contracting foodborne diseases. Antigen-based assays and polymerase chain reaction (PCR) panels, which are more rapid and sensitive than culture-based tests, are replacing them. Food safety in the twenty-first century will be eventually ensured by close cooperation between all the stakeholders. Using nucleic acids, antibodies, and other biomarkers assays analysis, cutting-edge technology like Nuclear Magnetic Resonance (NMR) in combination with nanoparticles may detect various target microbial infections' DNA or proteins. Food producers, distributors, handlers, and vendors are primarily accountable, and consumers must exercise caution and education. To protect public and individual health, government authorities must enforce food safety legislation. Medical professionals must continue to be committed to preventing foodborne infections and may think about treating diseases with safe diet treatment when done properly and under the direction of a doctor.

BACKGROUND INFORMATION AND HISTORICAL CONTEXT

Food security is a fundamental human right.

Unsafe food puts billions of people around the globe at risk. Every year, bad food causes hundreds of thousands of deaths and millions more illnesses. Consequently, healthy food saves lives. A healthy diet improves both individual and societal well-being. The economic development of the area where food safety is practiced and improved is improved by safe food. Both strong research and just enforcement of the law are essential to a safe food supply.

As technology develops, new laws must be passed to safeguard a steady stream of foodstuffs that are healthy and safe for people's health and well-being.

Chemical, biological, personal hygiene and environmental accidents are obstacles and tragedies in food safety. In the past, there have been several instances of food items being contaminated with industrial contaminants. Hundreds of thousands of people became ill or died in occurrences that occurred in Japan, Iraq, the United States, and other countries.

The Minamata illness (methylmercury poisoning), which was initially identified in 1956 at Minamata Bay in Kumamoto Prefecture, Japan, is the most well-known. In 1965, a second outbreak struck the Niigata Prefecture in Japan around the Agano River.

Cerebellar ataxia, sensory disruption, a narrowing of the visual field, and problems speaking and hearing were all signs of this illness. When consumed, the methylmercury that was released accumulated in fish and shellfish and rendered them poisonous.

Food safety worries and possible pollutants will remain a significant health problem as living standards rise. Because food is a need for life as an energy source and nourishment, consumers demand the quality and safety of the things they purchase. Consumers often rely on the government to guarantee that all food goods are safe as well as that they are advertised to contain. For instance, a jar of olive oil marketed as 100% virgin olive oil needs to include everything on the label minus the naturally occurring trace components that are present in olive oil and cannot be removed entirely without contaminating the oil [1,2].

Due to the consumption of rice tainted with high levels of cadmium, Japan had an endemic disease known as "ItaieItai." According to a 1961 inquiry, the Kamioka Mining Station owned by Mitsui Mining and Smelting was responsible for the cadmium contamination, and the worst-affected regions were located 30 km downstream of the mine. It wasn't until 1968

that the Japanese Ministry of Health and Welfare officially declared that the symptoms of "itaieitai" sickness were indeed brought on by cadmium exposure [3].

A widespread PCB poisoning occurred in 1968 in northern Kyushu, Japan, as a result of rice oil that had been polluted with PCBs that had been heat-degraded during processing. Chloracne is a rare kind of skin illness that affected these sufferers. In addition, impacts on the liver, reproductive system, endocrine system, nervous system, and cancer have been reported. The name "Yusho" ailment, which means oil syndrome, was given to the illness. It should be recognized that Yusho was not intentionally cooking oil pollution [4,5].

Iraq experienced a significant mercury poisoning outbreak in the years 1971–1972, which was brought on by eating seeds that had been treated with organomercury chemicals. The seeds that were treated with fungicides before sowing was the origin of the organomercury, which was primarily used to prevent soil- or seed-borne fungal infections. These seeds caused tremors, disorientation, hallucinations, delusions, and seizures in patients [6].

Around 1979, cases involving food contamination resembled the one that occurred in Taiwan. Cooking oil tainted with PCBs and dibenzofurans (PCDFs) was found to be marketed to the general population. About 2000 persons drank tainted heating oil due to the volume of infected oil and the intensive processing, packing, labeling, distribution, sales, and consumption of the oil. According to a recent study, exposure to PCBs and PCDFs may alter the pattern of mortality even three decades later [7].

People who ingested tainted oil during recent (2014e5) oil accidents in Taiwan may have short-term or long-term health effects. A "fats and oils" injunction was issued by the US Food & Drug Administration (US FDA) in 1989 against brokers who sold and bought non-feed oils such as used industrial oil while labeling them for use in animal feed. Following the discovery of PCB residue in turkeys sold for human consumption, one case developed. The PCBs were linked by FDA field investigators to waste oils from a chemical plant's scum pond that were designated as "industrial waste unsuitable for animal feed use." Further research revealed that traders "buy and sell" oil tankers and railcars, billing the goods to feed makers as feed grade regardless of the source. It's possible that the producer mixed it with other fats and oils to drastically dilute both its original identity and any impurities. Due to the proactive FDA field investigators program and cutting-edge food toxicity laboratory, which prevented a serious disaster, this US incidence did not spread widely [8].

Concerns about food safety persist in the twenty-first century. Due to the speed and breadth of product distribution, local epidemics might develop into global problems. On every continent, there have been severe epidemics of foodborne illness. 300,000 newborns and young children were impacted by the melamine poisoning of baby formula in 2008 in China alone; 51,900 of them required hospitalization, and six of them passed away. Future concerns including cancer or developmental retardation have also been brought up [9,10].

In addition to kidney impairments. 53 people died as a result of the Enteropathogenic *Escherichia coli (E coli*) outbreak in 2011 that was caused by tainted fenugreek sprouts in Germany. Cases of the outbreak were documented in 8 different countries throughout Europe and North America. The 2011 E. coli epidemic in Germany cost farmers and businesses US$ 1.3 billion in damages, and 22 European Union Member States received US$ 236 million in emergency help [11].

Food safety risks are a concern for world health. Young people, the elderly, and those who are ill are particularly at risk. If food supplies are insecure, people will switch to less nutritious diets and eat more "unsafe foods," which offer health concerns due to chemical, microbiological, and other dangers. This would increase healthcare expenditures and deplete the country's wealth [12].

Food safety in the 21st century should go beyond improving nutritional profiles, ingredient transparency, and regulations of unhealthy foods to include routine monitoring, surveillance, and enforcement of food products in support of the general public's health and the prevention of foodborne illnesses in light of recurrent food contamination incidents [13]. The Center for Science in the Public Interest provides thorough surveillance and documentation of foodborne disease outbreaks from 1997 for up-to-date information [14].

Why is a reliable food source necessary?

Due to the substantial economic burden that diseases place on society and the country, a secure food supply is crucial. Each year, foodborne diseases cause 325,000 hospital admissions and 5000 fatalities in the US alone [16]. More than one billion (1,000,000,000) bouts of food poisoning-related diarrhea are thought to occur yearly worldwide [16], and these poisonings are thought to be the cause of nearly 3 million child fatalities annually, primarily in developing nations.

In both developing and industrialized nations, foodborne diseases linked to microbial pathogens or other food pollutants represent a severe health danger. According to WHO estimates, fewer than 10% of cases of foodborne illness are recorded, whereas less than 1% of cases occur in underdeveloped countries [17]. WHO forecasts 600 million cases of foodborne diseases and 420,000 fatalities in 2010 in a new report. Norovirus and Campylobacter spp. were the diarrheal disease agents that were the most common causes of foodborne illness. Hepatitis A virus, Taenia solium, Salmonella typhi, and mycotoxins, particularly aflatoxins, were additional significant causes of foodborne mortality [18, 19].

From an economic standpoint, having access to enough safe and nourishing food is essential for supporting life, fostering good health, and fostering economic growth. One research found that the enhanced cost-of-disease model had an average cost per case of foodborne illness of $1626 while the basic model had an average cost per case of $1068 (both in US dollars). The resulting total yearly cost of disease for the upgraded and basic models was $77.7 billion and $51.0 billion, respectively. The basic cost-of-illness model is defined in the study to include economic estimates for medical expenses, lost productivity, and illness-related death. The more comprehensive pain, suffering, and functional impairment assessment based on monetized quality-adjusted life year estimates replace the productivity loss estimates in the improved cost-of-illness model [20].

Foodborne infections and their impact

Foodborne illnesses, including 9.4 million brought on by recognized pathogens, are thought to be the cause of 48 million illnesses in the US each year, according to the US Centers for Disease Control. Scombroid toxin/histamine and fish (317 outbreaks), ciguatoxin and fish (172 outbreaks), Salmonella and chicken (145 outbreaks), and norovirus and leafy vegetables were the pathogen-commodity pairings most often responsible for outbreaks (141 outbreaks). Norovirus and leafy vegetables were the pathogen-commodity pairs most frequently linked to outbreak-related illnesses (4011 illnesses), followed by Clostridium perfringens and poultry (3452 illnesses), Salmonella and vine-stalk vegetables (3216 illnesses), and C. perfringens and beef (2963 illnesses) [21,22]. Unsafe food items that frequently involve these risks include raw shellfish, undercooked animal meats, and produce that has been feces-contaminated. 2015 WHO study estimates the frequency of foodborne diseases, fatalities from these illnesses, and Disability Adjusted Life Years (DALYs), a measure of the burden caused by foodborne linked morbidity and mortality. The Global Burden of Disease project

and the DALYs statistics are both compatible because they are based on parameters set out by WHO [18]. 33 million DALYs were caused by these foodborne risks together, 40% of which were among children under the age of five. The impact of the huge worldwide burden of foodborne illnesses and fatalities is felt most acutely by young children living in low-income areas where standards of food hygiene and water sanitation are subpar. Therefore, enhancing personal, chemical, microbiological, and environmental health will enhance both children's and adults' total health.

It should be highlighted that the formation and spread of resistant bacteria have been related to antibiotic abuse and misuse in veterinary and human medicine, making the treatment of infectious illnesses in both animals and people inefficient [24].

Bacteria: Among the most prevalent foodborne pathogens are Salmonella, Campylobacter, and Enterohemorrhagic Escherichia coli (EHE coli). Fever, headache, nausea, vomiting, stomach discomfort, and diarrhea are among the symptoms. Eggs, poultry, and other goods made from animals are among the sources of salmonellosis. Drinking water, raw or undercooked chicken and raw milk are all sources of food-borne Campylobacter. Unpasteurized milk, undercooked meat, and fresh fruits and vegetables are all linked to EHE coli. Stillbirths and spontaneous abortions are more likely to occur when there is a listeria infection. Listeria may develop at refrigerator temperatures and is present in unpasteurized dairy products as well as several ready-to-eat items. People become infected with Vibrio cholerae through tainted food or water. Abdominal discomfort, vomiting, and diarrhoea with plenty of fluids are some of the symptoms, which can cause severe dehydration and even death.

Viruses: Norovirus infections cause violent vomiting, watery diarrhoea, and discomfort in the abdomen. Hepatitis A virus-infected food handlers are a frequent source of contamination, and the infection usually spreads through undercooked or raw seafood or contaminated raw veggies. Some parasites, like fish-borne trematodes, can only spread through ingested food. Some, like Echinococcus spp., may infect people through their food or close contact with animals. Other parasites, such as Ascaris, Cryptosporidium, Entamoeba histolytica, or Giardia, can contaminate fresh fruit by entering the food chain through water or soil.

Worms: The types of worms that are most common in areas where proper food preparation and storage, personal hygiene, water sanitation, and environmental health aren't regularly followed include cestodes, nematodes, trematodes, and helminths.

Chemicals: Environmental contaminants and naturally existing poisons have been responsible for several epidemics. Additionally, chemical residues that were employed to get rid of or manage worms and bugs might also provide a danger for foodborne illness. Natural poisons include mycotoxins, marine biotoxins, cyanogenic glycosides, and deadly mushrooms. Mycotoxins like aflatoxin and ochratoxin can be found in high concentrations in staple foods like corn and grains. Long-term exposure can harm the immune system, impair growth, or even result in cancer. Pediatricians and public health professionals are growing increasingly concerned about environmental toxins. Compounds known as persistent organic pollutants (POPs) build up in both the environment and the human body. Byproducts of industrial operations and garbage incineration include dioxins and polychlorinated biphenyls (PCBs). They are present in the environment and build up in the food chains of animals. Dioxins are very hazardous, and they can harm the immune system, interact with hormones, impair development, and even cause cancer. Finally, renal and brain damage can be brought on by heavy metals including lead, cadmium, and mercury.

Diagnostic advances to ensure food safety

Food has grown to be a significant route for human exposure to pathogenic microorganisms that cause foodborne illness, entering at various points along the value chain as a result of the globalization of the food trade [23].

Therefore, producers, processors, distributors, and consumers of food all face difficulties in tracing and detecting microorganisms, particularly pathogenic bacteria, in foods back to their sources. Also, medical professionals and diagnostic challenges are routinely presented to epidemiologists, and treatment uncertainty for patients who may have infectious diseases that are food-borne at the point of care. Rapid and precise foodborne pathogen detection is Vital for public health biosurveillance to stop food-borne illnesses and guarantee food safety. Detection Microbial techniques have advanced throughout time [25-27].

In general, culture-based diagnostic procedures are being replaced with quicker, more accurate culture-independent diagnostic techniques such as PCR panels and antigen-based assays [28].

These tests, however, are mostly employed in public health laboratories and are not easily accessible to professionals working in the industrial and therapeutic domains. Applications not dependent on culture are becoming more significant. Primarily because they produce outcomes pretty quickly when compared to approaches based on culture. Several various diagnostic tools to find pathogenic microbes in food and animals, including Salmonella and Vibrio spp.Ideally, due to the ease of assay and instrumentation, microbial diseases and pollutants can be detected in the field at a cheap cost. This will guarantee greater sampling. The efficiency of the target analyte due to the larger sample volume measurement identifies with over 100% specificity and precision due to orthogonal measuring [29].

Of biomarkers that can be detected in a variety of sample types, including blood, water, fruit, animal tissue, soil, and excrement. The objectives are to reduce overhead costs and save time owing to faster detection. For many of the diseases of interest in agriculture, animal farming, aquaculture, wild captured animals, and food safety in general, Point of Need Test (PONT) equipment for field diagnostics does not yet exist.

NMR-nanotechnology

In the same device chamber that conducts assays utilizing nucleic acids, antibodies, and other biomarkers, the Nuclear Magnetic Resonance (NMR) nanotechnology platform identifies several target microbes hybridizing with the pathogen's DNA or protein [30].

Through the use of many biomarkers from a single microorganism in the same detection equipment, orthogonal confirmatory studies can be accomplished.

This improves specificity and accuracy, acting simultaneously as a screening and a confirming instrument. Due to the normal amplification process and signal amplification by the nanoparticles, it is more sensitive than previous systems and has a dynamic range of 8 logs before saturation. As a result, this method improves the sensitivity and specificity of target microorganism detection. While protein structure can be amplified using the antibody ligands technique, DNA can be amplified using end-point PCR. The ability to examine numerous biomarker measures by multiplexing with high sample volumes further boosts the specificity of the detection method.

PCR-based

The production of sufficient numbers of cells for ELISA and other PCR-based assays (which might take up to 24 hours) depends on substantial enrichment. The essay needs DNA amplification and detection after enrichment. From enrichment to detection, the complete procedure could take several hours to many days. Such a detection system could not be as useful as PONT devices due to sample preparation procedures and auxiliary lab equipment (shakers, incubators, and microplate readers). Another frequently used technology is based on real-time or standard PCR (qPCR), depending on the instrument, and it can take up to 3.5 hours to detect something. The technology is only capable of employing the PCR method, making it unable to detect various biomarkers. [31,32].

Medical provider's role in food therapy

Most medical experts have concentrated on curing ailments without looking for those that are brought on by prolonged exposure to harmful foods and food products. Some dietitians have the propensity to continue counting the calories from macronutrients while ignoring the addition of chemicals to foods and food products that have no nutritional value. For commercial reasons, the food sector might prioritize ongoing profit over the general public's health.

A notable example is ketogenic diet therapy for epilepsy. Although this medicinal dietary therapy dates back at least 100 years, it was gradually discontinued over the following 50 years due to the development of antiepileptic medications [33,34].

About 20 years ago, this strategy was resurrected due to the resistance of 40% of epileptic patients to antiepileptic drugs. The ketogenic diet is expanding its therapeutic efficacy beyond epilepsy to include diabetic mellitus, cancer, and many specific neurological illnesses as a result of its medically promising indications [35–37]. It is therefore impossible to overstate the significance of medical professionals in dietary treatment. For many years to come, the late Professor Ja-Liang Lin, also known as Lin Chieh-liang [38], a renowned toxicologist and nephrologist, has left behind a significant legacy that serves as a model [39] for medical professionals to fulfill their responsibility to enhance and protect the quality and safety of Taiwanese and global food supplies.

The function of the government in enforcing food safety laws

Both strong research and just enforcement of the law are essential to a safe food supply. To further safeguard a steady supply of food items that are secure and wholesome for people's health and well-being, new rules and regulations must be periodically passed.

In most nations, the Food and Drug Administration (FDA) or a comparable agency's main mission is to assume responsibility for enforcing food safety laws to achieve three goals that promote public health and safety: (1) Educate the public on nutrition and key food product ingredients; (2) hold the food business accountable for compliance with current rules and regulations to assure the supply of safe food products, and (3) investigate and eliminate potential toxic contaminants and prosecute economic fraud via regular monitoring and surveillance on the chain of food supply.

Once rules are passed, they must be upheld to guarantee that the whole food sector, including those involved directly or indirectly in food production, labeling, packaging, distribution, and retail sales, complies. The FDA is granted the resources and power to create rules and regulations and to collect specialists as either agency employees or consultants to achieve its three-pronged goal of educating, enforcing, and removing any danger or safety issue relating to food [40]. In the years following September 11, some have suggested extending FDA's latitude in the fight against terrorism, particularly about the agency's power to keep an eye on and inform the public about any potential health risks associated with food, dietary supplements, over-the-counter medicines, and other consumer health products [41].

The foundation for establishing the rules and procedures to inform, enforce, and get rid of harmful foods must be based on good science if food safety laws are to be fairly applied. The concern about food contamination is placed in the correct perspective by the scientific process of risk assessment. The goal of scientific risk calculation is to provide the most accurate estimation of the genuine risk using current and accessible data. Research on animal toxicity as well as any reports and studies on humans that are accessible are thoroughly examined and evaluated for relevance and validity. The substance's safety and purity must be established scientifically by the sponsor (often the food maker). The sponsor must also show that any residues in a food product do not constitute a short-term or long-term risk to people's health. The government may demand that the sponsor do chronic feeding trials on animals if toxicological investigations indicate that a pollutant may cause cancer. The FDA utilizes a conservative risk assessment process to establish how much contamination poses no

appreciable risk of cancer to consumers if the results reveal that the chemical causes cancer. According to this process, the FDA permits a maximum lifetime cancer risk of one in one million (i.e., if one million consumers consumed the contaminant for a total of 70 years, one of them may get cancer as a result of the medication or chemical residue). The likelihood of such a danger is almost ten times lower than the likelihood of getting hit by lightning [42-47].

Tools and programs to guarantee the security of the food supply

Generally speaking, periodic food monitoring offers a 95% certainty that any targeted food's microbiological or chemical contamination will be found if it affects more than 1% of product batches. Investigating and regulating the transportation of potentially contaminated goods is done through food surveillance. The executive arm of the government grants the field inspectors the authority of the agency. If anonymous tips seem sufficiently suspected of wrongdoing, such as confusing labeling or originating from suspect sources, some food goods may be subjected to surveillance testing. To guarantee fairness, contaminants that are beyond regulatory limits must be retested in split samples sent to two different laboratories. In many nations, the voluntary report of "accidental" exposure programs has been successful. Without any intentional or knowing usage of contaminated items, such as microorganisms, pesticides, industrial chemicals, or natural toxicants, food products may inadvertently get exposed to contaminants. In this situation, the producer or retailer may voluntarily notify FDA of the contamination. The FDA may then dispatch a highly qualified consultant to offer the food business regulatory and scientific support. Consultant or laboratory fees could need to be paid by the business owner or organization, depending on the type and scope of the consultation [48].

To guarantee the security of the present and future food supply in the US, systems like the Food Safety and Inspection Service (FSIS) must be put into place. Risk management, which will reduce accidents and guarantee a secure supply of food, includes routine monitoring, surveillance, and voluntary reporting or recalls [50]. The US FDA has adopted the Pathogen Reduction/Hazard Analysis & Critical Control Points System to better address the hazards to food safety and better allocate inspection resources [48-50].

Future food safety

Food safety satisfies a basic human need. It supports global trade and tourism, encourages sustainable development, and aids in ensuring food security. The result of the expanded

consumer demand for a wider variety of foods that have been driven by globalization is a longer and more intricate global food chain. As the world's population grows, the intensification and industrialization of agricultural and animal production to meet the growing need for food bring both opportunities and challenges for food safety. Vendors, distributors, food handlers, and food producers must bear the primary responsibility for maintaining food safety. Consumers must be cautious and knowledgeable about dangers to food safety.

On the international market, legal professionals seem to be more active in promoting food safety. To take the lead in tackling food safety, doctors and healthcare professionals should be as passionate. After all, a population with access to healthy food is generally healthier. Ultimately, establishing meaningful food safety for every individual from a global viewpoint should be the objective of close cooperation between all stakeholders, regardless of who is taking the lead in the field of food safety [51-55].

SUMMARY

In conclusion, there is a connection between nutrition and food safety. Infants, small children, the elderly, and the ill are all affected by the vicious cycle of sickness and starvation brought on by unsafe food. Collaboration between governments, producers, suppliers, distributors, and consumers will eventually secure food safety in the 21st century because food supply chains span several national and regional borders.

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