

The Food Industry's Current and Future Role in Preventing Microbial Foodborne Illness Within the United States

Michael P. Doyle,^{1,2} Marilyn C. Erickson,^{1,2} Walid Alali,^{1,2} Jennifer Cannon,^{1,2} Xiangyu Deng,^{1,2} Ynes Ortega,^{1,2} Mary Alice Smith,^{1,3} and Tong Zhao^{1,2}

¹Center for Food Safety, ²Department of Food Science and Technology, and ³Department of Environmental Science, University of Georgia, Athens

During the past century, the microbiological safety of the US food supply has improved; however, many foodborne illnesses and outbreaks occur annually. Hence, opportunities for the food industry to improve the safety of both domestic and imported food exist through the adoption of risk-based preventive measures. Challenging food safety issues that are on the horizon include demographic changes to a population whose immune system is more susceptible to foodborne and opportunistic pathogens, climate changes that will shift where food is produced, and consumers' preferences for raw and minimally processed foods. Increased environmental and product testing and anonymous data sharing by the food industry with the public health community would aid in identifying system weaknesses and enabling more targeted corrective and preventive actions. Clinicians will continue to play a major role in reducing foodborne illnesses by diagnosing and reporting cases and in helping to educate the consumer about food safety practices.

Keywords. foodborne illness; food industry; Food Safety Modernization Act; whole-genome sequencing; imported food.

Within the United States, Americans have been fortunate to have an abundant food supply that is provided by a complex network of food producers, processors, distributors, and retailers. Despite technological advancements within the food chain, it is a sobering realization that the Centers for Disease Control and Prevention (CDC) estimates that annually 1 in 6 Americans (or 48 million people) becomes ill, 128 000 are hospitalized, and 3000 die of foodborne diseases, either from 31 known pathogens or by unspecified agents [1, 2]. Although chemical contamination and antibiotic resistance are important components of food safety, this article will focus on reducing microbiological contamination and is targeted to clinicians who play a critical role on the front line of diagnosing and

treating patients suffering from foodborne illnesses. Hence, this article is intended to provide clinicians a better understanding of the challenges and needs the food industry faces in providing safe foods to consumers.

EVOLUTION OF FOOD SAFETY ADVANCES IMPACTING THE FOOD INDUSTRY

Over the past 150 years, major changes in the way food is produced, processed, transported, retailed, and consumed emerged with the country's urbanization and modernization. As advances in food science and technology coincided with developments in the basic sciences and public health, a new understanding of microbiological pathogens contributing to foodborne diseases evolved. Reflecting the state of science and technology of the times, food safety legislation and science-based recommendations for safe food production, processing, and distribution were enacted (Table 1).

Generally, food producers and processors comply with regulatory food standards and recommended

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Correspondence: Michael P. Doyle, PhD, Center for Food Safety and Department of Food Science and Technology, University of Georgia, 1109 Experiment St, Griffin, GA 30223-1797 (mdoyle@uga.edu).

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Table 1. Historical Background and Major Food Safety Regulations and Recommendations During the 20th and 21st Centuries^a

Legislation	Description
1906 Federal Meat Inspection Act & Pure Food and Drugs Act	Unsanitary conditions at meat processing facilities and the rampant practice of misbranding and economic adulteration of foods with cheaper ingredients led to the 1906 passage of these 2 important acts, which became the basis for all 20th-century legislation upheld by the USDA and what was to become the FDA in 1931. USDA was to primarily oversee animal health just prior to slaughter and the sanitary conditions of slaughter facilities. FDA was to oversee all other foods and drugs and, later, cosmetics. Both pieces of legislation were updated in 1938 for clarifications and specific labeling requirements.
1958 Food Additives Amendments	A major change to how foods were regulated, requiring evaluation of individual food ingredients rather than a food product in its entirety. The term “safety” was applied for the first time, and the concept of “Generally Recognized as Safe” was applied to food additives that had been approved for use in foods prior to this amendment. This was the last major change to the safety of FDA-regulated foods until 2011.
1967 Wholesome Meat Act	This law strengthened meat inspection program standards and quality and expanded labeling requirements. Inspection oversight of poultry and egg products were also expanded in the 1968 Wholesome Poultry Products and the 1970 Egg Products Inspection acts. The USDA’s FSIS, charged with meat and poultry quality and safety inspections, was born in the late 1970s and landed its current name (FSIS) in 1981.
1996 Pathogen Reduction/Hazard Analysis Critical Control Point Rule	HACCP was first developed in the late 1960s by Pillsbury Company in conjunction with NASA to ensure the safety of foods consumed by astronauts in space. This system was accepted among many food production and processing industries by the 1990s. FSIS enacted the first HACCP legislation in 1996. HACCP is a 7-step approach to identify potential biological, chemical, and physical hazards and processing steps likely to control these hazards, establish and monitor limits for preventive measures, and establish corrective actions, record-keeping, and verification programs for the proper function of the HACCP program. As scientific discoveries and technologies emerge, HACCP programs are modified to maintain their scientific relevance; thus, HACCP and HACCP-based programs are considered “science-based.”
FDA Food Safety Guidance Documents	Since the late 1990s, commodity-specific guidelines were developed (and often revised) for the safe handling of agricultural products during production, processing, and distribution. These documents, while not industry requirements, became minimal standards for the food industry and many are still in place today. For a comprehensive list of Guidance Documents, see http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ .
2011 Food Safety Modernization Act	This overhaul of food safety legislation awaits development of the specific regulations, but it is clear that an HACCP-based approach for the safety of all foods will be taken. Key elements to FSMA include (1) documentation and implementation of a food safety plan for all food processing facilities earning significant profits; (2) a produce safety rule, specifying science-based standards for safe on-farm practices for farmers of produce consumed raw; (3) imported foods to be held to the same prevention-oriented standards as domestic foods; and (4) an enhanced system of tracking and record-keeping for food products through the food chain. FSMA also establishes a mandated inspection program, working with state, local, and foreign governments, along with accredited third-party certification bodies for foreign food facilities.

Abbreviations: FDA, Food and Drug Administration; FSMA, Food Safety Modernization Act; FSIS, Food Safety and Inspection Service; HACCP, Hazard Analysis Critical Control Point; NASA, National Aeronautics and Space Administration; USDA, United States Department of Agriculture.

^a This is not meant to be a comprehensive list of all food safety legislation, but rather highlights significant events and provides a historical background for discussions within this manuscript.

food safety practices, but their degree of commitment to promoting a strong food safety culture varies. Compliance often depends on a company’s culture and the willingness of the senior management to absorb the additional costs. For example, personal injury litigation provides only a weak incentive to improve a corporation’s food safety efforts [3], as the possibility of being sued for foodborne illness is often considered low and, if sued, the compensatory damages are often relatively small, with minimal negative public relations consequences. Moreover, although the financial impact of recalls may be as high as \$30 million [4], a few companies may decide that it is more cost-effective to “roll the dice” than it is to provide many of the food safety interventions that are available. Fortunately, most

food companies not only comply with existing regulations, but have implemented additional measures to ensure that their products are safe.

Currently, 2 approaches are used to gauge the progress of the industry’s food safety programs. The definitive approach involves monitoring the occurrence of foodborne diseases in the population primarily through the identification and reporting of cases by clinicians. Additionally, science-based performance and microbiological standards for levels of pathogen contamination (product testing) are applied under the assumption that if products not meeting these production standards are removed from the market, the incidence of foodborne disease will decrease. Using these tools, it has been revealed that the number

of outbreaks and illnesses for *Escherichia coli* O157:H7 has been reduced by 50% during the past 15 years [5]. In contrast, *Campylobacter* infections have continued to increase after a modest decline in the late 1990s [6, 7], and *Salmonella* infections have neither substantially increased nor declined [5,7], as some food sectors have seen improvements and others (ie, low-moisture food products and fresh produce), not previously recognized as risky, are now considered to be of significant risk.

CURRENT STATUS OF FOOD SAFETY INITIATIVES THAT WILL IMPACT THE FOOD INDUSTRY

Recognizing that the complexity of today's food safety system requires a proactive approach to predict where problems might arise, rather than detecting them after they have occurred [8], the food industry and regulatory authorities have adopted a food safety system that is focused on science-based prevention of food safety problems and on products and foodborne pathogens associated with a large number of outbreaks [5], such as *E. coli* O157:H7, *Salmonella* and *Listeria monocytogenes* in leafy greens, sprouts, dry foods, and ground meat and poultry products. As part of these efforts, The Food Safety Modernization Act (FSMA) was signed into law in January 2011, but implementation currently awaits adoption of specific regulations. When fully implemented, the food industry will be required to apply science- and risk-based preventive measures at all appropriate points across the farm-to-table spectrum to ensure the safety of foods (Table 1). This new food safety system will undoubtedly have some unanticipated weak links during its early stages of implementation. However, over the long term, this new and improved food safety system should lead to a safer food supply and, in turn, to a reduced burden of foodborne illnesses.

Inherent to the implementation of FSMA and its science-based food safety programs is the acknowledgment that there will still be some level of risk of acquiring foodborne illness from eating food because zero risk is not practically achievable [9, 10]. Quantitative microbial risk assessment (QMRA) can help define the level of acceptable risk and the associated performance and microbiological standards. Using QMRA, the actual risk to public health (based on surveillance data) is related to the levels of a microbiological hazard ingested through food at consumption, and those levels are in turn dependent on the initial contamination levels and modifying influences during processing and distribution [11]. For instance, the World Health Organization/Food and Agricultural Organization of the United Nations QMRA models for *L. monocytogenes* in ready-to-eat food have revealed that most cases of listeriosis are associated with consumption of food contaminated with higher *L. monocytogenes* numbers than the current standards of zero tolerance

or 100 colony-forming units per gram [12]. However, the data needed for QMRA are not always available or in the correct format [8]. Therefore, there is a need for epidemiologic studies and surveillance programs to fill the gap where data for these models are not available, as well as to provide independent assessment of the sources of illnesses. As new information becomes available (ie, the ecology of foodborne pathogens, the efficiency of alternative pathogen control approaches, the major sources of illnesses), microbiological and performance standards should be changed to align them with the state-of-the-science knowledge of the food system. Collection of environmental and finished product testing data should be continued and possibly enhanced to identify weaknesses that may occur post-FSMA implementation. Assessment of progress—fewer illnesses, hospitalizations, and deaths—requires robust human surveillance systems for sporadic illnesses and outbreaks that supply data needed to estimate the incidence of illness caused by each pathogen, and the exposures that result from those infections.

ADVANCES IN MOLECULAR METHODS, SURVEILLANCE SYSTEMS, AND QUALITY ASSURANCE PROGRAMS THAT WILL REVOLUTIONIZE FOODBORNE OUTBREAK INVESTIGATIONS

Another essential component to help ensure the successful implementation of FSMA is the evaluation of the effectiveness of its individual components through the ongoing monitoring of human illness by the CDC's foodborne disease surveillance systems that receive data from local, state, and territorial health departments. Each state has a list of diseases that must be reported by clinicians or clinical laboratories. There are several key components of the CDC foodborne disease surveillance system (Table 2), but fundamental to this system is PulseNet, which applies molecular subtyping of foodborne pathogens to detect clusters of human illnesses caused by similar strains. PulseNet is in the midst of incorporating a new tool, whole-genome sequencing (WGS), that will revolutionize foodborne outbreak detection and investigations. Facilitating the adoption of this new technology has been the enormous reduction in the cost to sequence an entire bacterial genome, from \$3500 in 2007 to \$50–\$70 in 2014 [13, 14]. In the era before WGS matured, diagnostic subtyping of foodborne pathogens relied primarily on pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing, but these molecular profiling techniques are laborious, time consuming, and difficult to standardize between different laboratories, and all rely on pure cultures and therefore are at odds with the increasing use of culture-independent diagnostics [15]. The bacterial fingerprint provided by WGS, although still requiring highly trained personnel and expensive equipment, offers substantially more genetic information than

Table 2. Selected Surveillance Systems Within the Centers for Disease Control and Prevention Used for Detecting or Monitoring Foodborne Illnesses and Outbreaks in the United States

Surveillance System	Description of Surveillance System
PulseNet	A national network of public health and food regulatory agency laboratories (spans 50 states and 82 countries) that perform standardized molecular subtyping (“fingerprinting”) of foodborne disease-causing bacteria (<i>Escherichia coli</i> O157 and other Shiga toxin-producing <i>E. coli</i> , <i>Campylobacter jejuni</i> , <i>Clostridium botulinum</i> , <i>Listeria monocytogenes</i> , <i>Salmonella</i> , <i>Shigella</i> , <i>Vibrio cholerae</i> , and <i>Vibrio parahaemolyticus</i>).
FoodNet	An active surveillance system with >650 clinical laboratories providing input of laboratory-confirmed cases of <i>Campylobacter</i> , <i>Listeria</i> , <i>Salmonella</i> , Shiga toxin-producing O157 and non-O157 <i>E. coli</i> , <i>Shigella</i> , <i>Vibrio</i> , <i>Yersinia</i> , <i>Cryptosporidium</i> , and <i>Cyclospora</i> . Information from FoodNet is used to assess the impact of food safety initiatives on the burden of foodborne illness with the surveillance area encompassing 15% of the US population.
CaliciNet	This database is used by public health laboratories (now operational in 28 states and the District of Columbia) for submission of genetic sequences of norovirus strains, and epidemiology data from norovirus gastroenteritis outbreaks. The norovirus strains can be compared with other strains in the database, helping the Centers for Disease Control and Prevention link outbreaks to a common source, monitor norovirus strains that are circulating, and identify newly emerging norovirus strains.
FoodCORE	Coordinated Outbreak Response and Evaluation Network, whose goals are to streamline decision making, respond more quickly to outbreaks, and ensure seamless coordination and enhanced communication. Group will also standardize postresponse activities such as environmental assessments and root cause analysis, thus providing an opportunity to learn from mistakes and use that information to drive strategies to prevent outbreaks from occurring in the future.
NORS	The National Outbreak Reporting System collects reports of foodborne outbreaks from state, local, and territorial public health agencies, who in turn collect their data from clinicians. Analysis of these data is conducted to improve understanding of the human health impact of these outbreaks and contributing factors involved in these outbreaks. The system that preceded NORS was called the electronic Foodborne Outbreak Reporting System (eFORS) or OutbreakNet.
NVEAIS	National Voluntary Environmental Assessment Information System—information collected will be used to establish a detailed characterization of food vehicles and their trends, identify and monitor contributing factors and their environmental antecedents, and provide a basis for hypothesis generation regarding factors that may contribute to foodborne outbreaks.

the current techniques to allow more discriminatory and feature-rich subtyping and characterization of strains. Furthermore, WGS provides the possibility for culture-independent subtyping through metagenomics approaches. As an example of its potential usefulness in an outbreak investigation, the CDC described how Canadian and CDC investigators used WGS of *Listeria* isolates from contaminated lettuce and from a patient in Ohio who reported consuming bagged lettuce and found a very close match that gave a level of confidence, not possible with PFGE, that the 2 isolates were linked [16]. It is envisioned that use of WGS results from human, food, and environmental sources, when paired with epidemiologic investigation that includes interviews with patients about exposures, will result in quicker identification of the food or other exposure that is the source of contamination. The GenomeTrakr network (<http://www.fda.gov/Food/FoodScienceResearch/WholeGenomeSequencingProgramWGS/ucm363134.htm>) is assembling a database of WGS results on food isolates that can be compared with similar data on clinical isolates obtained by PulseNet. With this information, effective control measures will be implemented more quickly, thereby resulting in a reduction in the number of illnesses associated with each outbreak. Moreover, as the capacity of public health and hospital laboratories to conduct WGS expands both nationally and internationally (Table 3), it is likely that there will be an increase in the

number of outbreaks recorded for which the causative agent is identified. Some of these “new” outbreaks will be caused by known agents that would have previously escaped detection, whereas others will be caused by agents that have not yet been identified, estimated now to be 50%–60% of the total number of foodborne illnesses [17]. If more outbreaks and illnesses are detected because of an enhanced surveillance system, it will be important that the public health community and other information sources carefully communicate to the general public that the food safety system has not likely deteriorated, but rather the surveillance system has improved in sensitivity and in its ability to detect causative agents that previously had not been identified.

Most food producers and processors have quality assurance programs that include testing for foodborne pathogens and/or indicator microbes in their facilities and/or products. Expanding their efforts in environmental and finished product testing would be advisable as results would aid in identifying system weaknesses. Unfortunately, testing results from industry have previously not been shared with others because of potential regulatory ramifications or for product liability reasons [18]. Collecting samples for WGS from food production sites and sharing these data would not only assist identification and traceback during outbreaks, but would also aid food processors in understanding the ecology of these pathogens. Similarly, the

Table 3. Selected Programs Designed to Build Capacity for Whole-Genome Sequencing in Future Projects

WGS Program	Description of Project
The 100K Genome Project	The University of California, Davis is sequencing pathogen isolates commonly transmitted by food that are stored in culture collections of FDA, USDA, and other worldwide partners to provide a genetic catalog. This approach will enable systematic definition of biomarker gene sets associated with persistence, serotype diversity, antibiotic resistance, pathogenesis, and host association and ultimately bring a new paradigm to the management of foodborne disease. Additional information on this project may be found at http://100kgenome.vetmed.ucdavis.edu/ .
CDC's Advanced Molecular Detection	Molecular sequencing and bioinformatics capacities are being upgraded at national and state levels to consistently use these tools as an aid to detect disease outbreaks. Additional information on this initiative may be found at http://www.cdc.gov/amd/ .
Global Microbial Identifier	A global database network for the identification of all types of microorganisms (bacteria, parasites, and fungi) that includes both genomic information and metadata (ie, epidemiologic or environmental details). Deployment into developing countries where systems are not yet entrenched but technological progress and market forces are looking to improve the health of their population would enable significant "leap-frog" potential for those countries. Consequently, this system is envisioned to be accessible to users in academia, industry, government, and clinical laboratories (eg, clinicians, veterinarians, epidemiologists, microbiologists) for single clinical tasks as well as for national and international public health surveillance and outbreak investigation and response. Additional information on this project may be found at the following website: http://www.globalmicrobialidentifier.org .
GenomeTrakr	New pilot network of state and federal public health laboratories collecting and sharing genomic data from pathogen isolates commonly transmitted by food. Currently includes 10 FDA field labs and 10 state public health laboratories. Additional information on this project may be found at http://www.fda.gov/Food/FoodScienceResearch/WholeGenomeSequencingProgramWGS/ucm363134.htm .
Center for Genomic Epidemiology	The aim of this center is to provide the tools for analysis and extraction of information from sequence data and internet/Web interfaces for using the tools in the global scientific and medical community. Additional information about this Center and the services and education programs it offers for clinicians may be found at http://www.genomicepidemiology.org .

Abbreviations: CDC, Centers for Disease Control and Prevention; FDA, United States Food and Drug Administration; USDA, United States Department of Agriculture; WGS, whole-genome sequencing.

sharing of food safety data gathered during federal inspections of meat, poultry, and egg product processing establishments would aid the industry in understanding possible weaknesses in their system. VoluntaryNet (VolNet), a recently launched joint initiative between the CDC, the University of Georgia's Center for Food Safety, and the food industry, is an initial step toward achieving this goal. In 2014, 429 *Salmonella* and 8 *L. monocytogenes* isolates were received from food companies. To minimize liability issues [19], foodborne pathogen isolates along with information on their source (environmental or food type) are provided to the Center for Food Safety anonymously for PFGE analysis, and the molecular patterns are submitted to CDC for inclusion in its PulseNet databases. Ultimately, it is envisioned that this information will (1) help the food industry and CDC identify emerging trends or pathogen strains of the greatest concern and understand the public health significance of these pathogens in specific foods; (2) enable companies to perform better by conducting more thorough food safety risk assessments with respect to food products, pathogens of concern, and country of origin; and (3) because PulseNet and CDC will be informed on source-pathogen combinations commonly detected by VolNet, this information will enable CDC and state health departments to design more targeted questionnaires for case-control studies used in the investigation of illness clusters and outbreaks (early

detection). On the assumption that the food industry will continue to support this effort, it is envisioned that WGS profiles will eventually replace PFGE fingerprints as part of the VolNet program.

IMPACT OF CHANGES IN GLOBAL CLIMATE AND ECONOMIC FORCES ON US FOOD PRODUCTION AND SAFETY

Erratic and extreme changes in climate can affect the microbiological safety of the US food supply by impacting the dispersion of pathogens in the environment and by modifying environmental conditions in which pathogens or their competitors must adapt to survive. Hence, changes in contamination risks will vary with location, as they would be dependent on net temperature shifts and precipitation patterns that occur for that area [20].

Nevertheless, to meet the need for water and consumer expectations of relatively low-cost produce, food imports are likely to increase [21] as they have been increasing for the past 10 years, at an average annual rate of 4% for vegetables, fruits, and nuts [22]. Ensuring the safety of imported food, however, requires a completely different strategy than that used for domestic food. One of the major concerns is that in many countries that export

food to the United States, the hygienic criteria established for their domestic production and processing does not meet the same level of hygienic criteria established in the United States [23, 24]. For example, practices prevalent within many developing countries include the use of fecal-contaminated irrigation water for fruit and vegetable production, the use of night soil as a soil amendment, and the use of untreated chicken manure and human feces in aquaculture production [25]. Such fecal wastes serve as vehicles of a variety of foodborne pathogens. In addition, production and processing establishments in developing countries often lack hygienic controls, various types of cleaning and sanitizing equipment, and quality assurance management systems [26].

These safety issues, along with the recognition that nearly 114 000 foreign food processing facilities [27] are registered to export nearly 10 million line items to the United States [28], led to proposed FSMA rules requiring importers to verify that preventive control systems and produce safety standards have been applied to food brought into the United States, and the food is not adulterated or mislabeled [28]. Ensuring compliance with those criteria, however, will be a formidable task for the Food and Drug Administration. As is the case with domestic food, only a certain number of samples can be tested, which may result in some contaminated food entering the US food supply. Clinicians can help in educating consumers of their need to be diligent in handling and storing food, so that if pathogens are present, they have little opportunity to grow before being consumed.

The demographic shift toward an aging and immunocompromised population is yet another emerging issue that can affect the number of outbreaks and severity of foodborne illnesses. The elderly often experience more serious outcomes than immunocompetent populations when infected by *Salmonella* or *L. monocytogenes* [29, 30]. In addition, opportunistic pathogens that are frequently associated with soil and vegetation, including fresh produce, may also present a growing problem as they infect the elderly and other immunocompromised individuals with greater frequency [6]. Hence, increases in foodborne outbreaks and illnesses will likely occur despite increased efforts by the food industry to reduce foodborne pathogens in their products. One possible solution to this dilemma that is similar to the approach in which hospitals are providing low-microbial meals to vulnerable patients [31] may be to design “extra-safe” food products, such as irradiated, sterilized, or pasteurized foods, that are targeted to higher-risk populations. If added convenience were also built into this niche product line, it would offer a greater incentive for the elderly to purchase the costlier items. In addition, educational tools describing the problem and possible approaches to minimize the problem should be made available. Such information could then be distributed through clinicians who specialize in treating this segment of the population.

CONSUMERS' BEHAVIOR CHANGING THE LANDSCAPE OF FOOD PROCESSING AND ITS IMPACT ON FOOD SAFETY RISKS

As lifestyles of US consumers become more diverse, demands for ethnic foods and semiprepared ingredients that facilitate “meal assembly” have arisen, requiring that safe food handling information for preparation, cooking, and storage be known and clearly conveyed to the consumer [32]. Alternatively, there are products such as unpasteurized milk and cheeses made from unpasteurized milk as well as minimally processed natural foods that contain no or reduced levels of antimicrobial additives that can be risky but are produced to meet consumer demand [33–35]. The dilemma then becomes whether food manufacturers should continue to produce those products or develop alternative interventions that mitigate the risk.

Over the years as foodborne outbreaks and food recalls have attracted increased media attention, consumers' awareness of the safety of foods has grown. Many consumers mistakenly believe they have little direct responsibility for ensuring the safety of their food [18]. Even when consumers have been provided facts on improving home hygiene through information campaigns, this knowledge often does not translate into noticeable changes in practice, and studies reveal a limited effect on reducing the actual level of bacteria present in a meal and on the associated risk of acquiring human illness [36]. For example, a recent study observing participants' food-handling practices in the kitchen found that 40% of the participants undercooked chicken [37]. Moreover, other studies have revealed that consumers have difficulty understanding labels describing the safe handling of food [38, 39]. The food industry could make food preparation more fail-safe by developing “smart” ovens and microwave ovens that would read food product bar codes and automatically heat the food to the temperatures needed to ensure that pathogens would be killed. If consumers applied insufficient temperatures or times needed to meet the advised specifications, warnings to the consumer could be displayed on the ovens.

Ensuring the safety of food products does not come without a cost to the food industry and ultimately the consumer. Hence, the food industry, as a whole, could be more proactive in advocating through multiple media outlets a positive message of the efforts being made to provide consumers with microbiologically safe foods. In addition, clinicians need to take a more active role in educating their patients, not only about the nutritional benefits of certain food groups, but the potential risks of foodborne pathogens and how they can reduce those risks.

CONCLUSIONS

The US food industry has undergone many changes during the past century that have affected its production and processing

practices and in turn, the microbiological safety of its products. Passage of the FSMA has initiated a transformation that should lead to further food safety-related enhancements in the industry, particularly with regard to imported foods. The surveillance system for foodborne illnesses will continue to improve dramatically. Improved surveillance tools (WGS and bioinformatics) will be at the disposal of public health and regulatory authorities to enable better identification, tracking, and earlier containment of outbreaks. Despite these efforts, other factors, such as climate change, pathogen evolution, an increase in the elderly and immunocompromised populations, and consumers' lack of knowledge on factors contributing to unsafe food in the home, could lead to increased foodborne illnesses and offset the progress the food industry continues to make toward mitigating foodborne pathogen contamination in its products. Improvements to the microbiological safety of our foods will therefore require the cooperation of the food industry, clinicians, educators, government, and consumers to reduce contamination and minimize exposure to foodborne pathogens.

Note

Potential conflicts of interest. All authors: No potential conflicts of interest.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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