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*Corresponding author
Malik A. Hussain, PhD
Adjunct Senior Lecturer
Department of Wine, Food
and Molecular Biosciences
Lincoln University, Lincoln
Christchurch, New Zealand
E-mail: malik.hussain@lincoln.ac.nz;
malikaltaf_ft@hotmail.com

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Microbial Safety of Foods in the Supply Chain and Food Security

Mohamed T. Elkhishin, MSc; Ravi Gooneratne, PhD; Malik A. Hussain, PhD*

Department of Wine, Food and Molecular Biosciences, Lincoln University, Lincoln, Christchurch, New Zealand

ABSTRACT

Most foodborne outbreaks in recent years have been linked to microbial contamination of food products. These food outbreaks can cause considerable food losses, and hence can play a role in global food insecurity. We discuss the importance of microbial food safety in the supply chain to reduce the potential for contamination. Microbial contamination may take place at pre-farming, farming or post-farming stages of the food supply chain. *Campylobacter, Salmonella, Listeria monocytogenes, Escherichia coli* O157:H7 and non-O157:H7 STEC *E. coli* are the most common pathogenic bacteria associated with food safety issues in the food supply chain. Efficient process controls and effective food safety management systems are vital elements to reduce microbial contamination and improve food security.

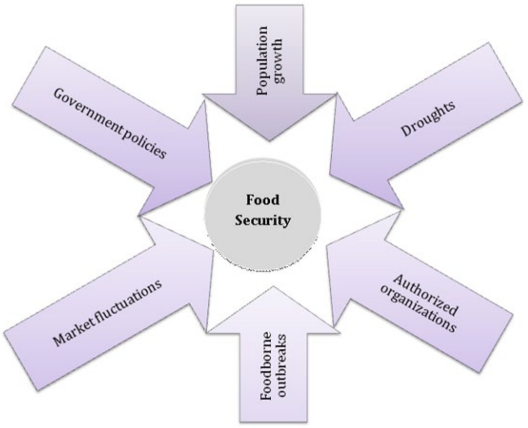
KEY WORDS: Food security; Food safety; Food supply chain; Microbial contamination.

ABBREVIATIONS: FSC: Food Supply Chain; FAO: Food and Agriculture Organization; STEC: Shiga toxin-producing *E. coli*; CDC: Centers for Disease Control and Prevention; CARMA: *Campylobacter* Risk Management and Assessment; COI: Cost-of-Illness.

INTRODUCTION

The difference between the terms "food safety" and "food security" is commonly misunderstood. These are separate issues but are, nevertheless, closely interrelated. The definition of food safety is the inverse of food risk and is the probability of a specific food not causing health problems after consumption.[1] Food security is defined as ensuring that all people at all times have both physical and economic access to the basic food they need.[2] Food security, a complex issue, is affected by multiple factors including microbial contamination of food, government policies, drought, global and national market fluctuations, and population growth (Figure 1). The importance of microbiological food safety is paramount because of the potential for harm-

Figure 1: Factors that Influence Food Security either Directly or Indirectly.



ful microorganisms to grow and multiply in food commodities.[3] Entry of possible contaminants such as microbiological agents into food is a threat to the safety of food products. This can result in food poisoning, increase in foodborne outbreaks and a decrease in food availability because of discarding the contaminated food products.[4] Drought also can significantly affect the availability of irrigation water used in agricultural production and cause crop failures.[5,6] The aforementioned factors affect food availability and food access and can result in an increase in global commodity prices and food market fluctuations.[7]

Globalization of the food trade is one of the factors responsible for the increased number of foodborne outbreaks caused by microbes.[8,9] Bacterial pathogens are the most prevalent contaminants in food products followed by viruses, pesticide residues and mycotoxins.[10] The presence of harmful bacteria on food surfaces can increase the risk of cross-contamination, causing food poisoning and/or food losses. Food safety in the manufacturing and production of foods is important to protect the consumer from potential health risks and to reduce food losses. Food safety and quality in the supply chains are crucial to achieving food security and allows food to flow from areas of surplus to areas of deficit in local, national and global markets.[11,12] Emphasis as a priority is on microbiological quality throughout the food production chain, to minimize the risk of foodborne illnesses and, consequently to improve food security.

The gap between the current global population and food production, as well as the difference between food supply and demand in many countries is widening.[13,14] Understanding the relationships between microbial contamination, food safety and food security, and how these affect the global food supply, will help highlight areas in the food supply chain (FSC) that require more attention to improve food security. Governmental organisations have therefore introduced more rigorous policies to reduce the risk of food contamination and, thereby, ensure the supply of safe food.[15]

This paper discusses how microbiological food safety in the FSC could be useful in improving global food security. For the purpose of explanation in this report, the term "food safety" will refer to foodborne microbial infections and outbreaks and "food insecurity" as food losses and microbial spoilage of food during and post-food production.

FOOD LOSSES AND WASTE IN THE FOOD SUPPLY CHAIN

According to the Food and Agriculture Organisation (FAO), the world produces enough food to feed everyone living on earth. However, each year, almost one out of every four calories produced to feed people is not consumed and about one-third of total food production (1.3 billion tonnes) was either lost or discarded during production in the FSC. The FSC has been defined as "the total supply process from agricultural production, harvest or slaughter, through primary production and/or manufacturing to storage and distribution to retail sale or use in catering and by consumers".[3] It is designed to positively influence quality, safety, sustainability, logistics and efficiency of food production and processing from the farm to the fork.[16] Food losses and waste can take place at any stage of the FSC, e.g., agricultural production, post-harvest, processing, distribution and consumption (Figure 2). The term food loss most commonly refers to food products that are intended for human consumption but have instead been lost in production, storage, transport and processing, mostly due to microbial contamination and/or spoilage.[17-19] Food waste occurs at the end of the FSC within the retail and final consumption stages and it refers to edible food products that have been discarded, degraded and not consumed by humans.[20]

For most countries, food losses and waste of fruit and vegetables are higher than for other products, such as dairy and meat.[21,22] Liu et al[23] reported that fruit and vegetables suffered losses of up to 20-30% compared to meat and aquatic products (>15% loss) in the FSC in China. According to FAO,[24] the losses related to fruits and vegetables in the FSC in Latin America were over 70% while the dairy and meat product losses were only 22% and 25%, respectively (Figure 3). Insufficient refrigeration facilities in the FSC, particularly during transportation are noted as a major factor in these losses. In developed countries better FSC management has led to a reduction of food losses compared to less developed nations. It is widely accepted that an improvement in food safety reduces potential microbial risks and opera-

Figure 2: Major Stages in the Food Supply Chain where Microbial Contamination is Likely to Occur.

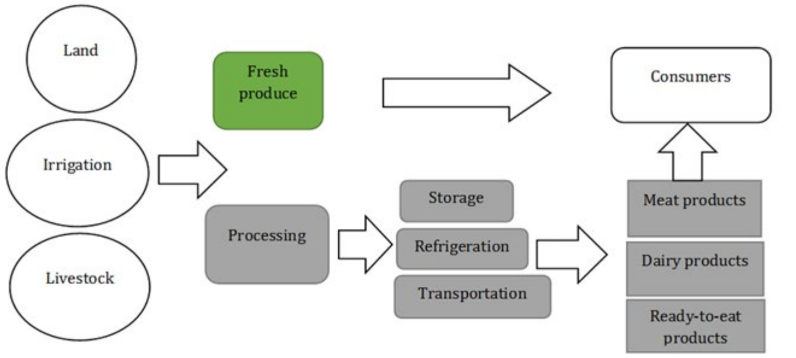
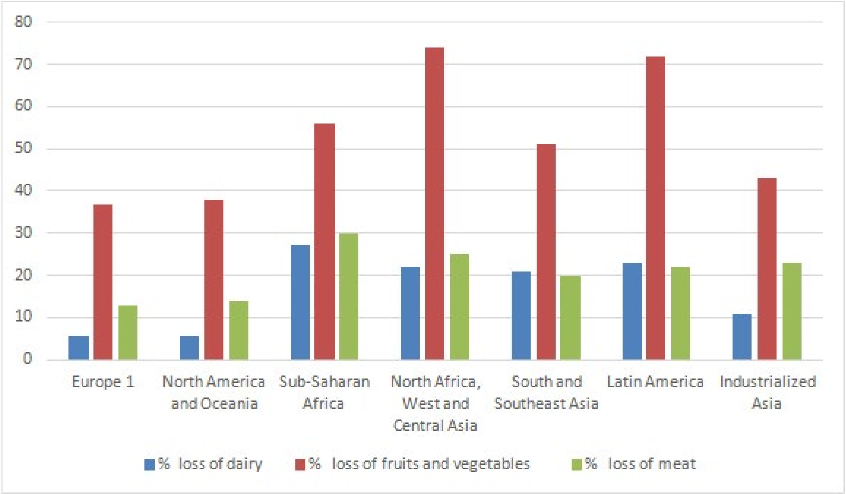


Figure 3: Total Supply Chain Loss of Dairy, Meat, and Fruit and Vegetable Products in Different Regions of the World.[24]



tional costs, both of which are vital in reducing food losses and foodborne outbreaks and thereby enhance food security.

Food may become contaminated with a range of microorganisms during harvesting, processing and handling operations as a result of the behaviour of farmers, retailers and consumers.[17,19,25] It is not well-documented how much food loss or wastage is caused by microbial contamination each year. However, the cost of foodborne illnesses caused by microbial pathogens can be used as an indicator to evaluate the extent of the contamination problem. For example, organisations such as the Centers for Disease Control and Prevention (CDC) in the USA provide details of the 48 million Americans annually who suffer from foodborne illnesses associated with identified microbial contaminants.[26] Buzby and Roberts[27] estimated that 70% of diarrhoeal diseases are foodborne. Thus it is clear that microbial pathogens are associated with a large number of foodborne outbreaks, which results in food losses. Hence, it is important to understand the common microbiological hazards in foods.

COMMON MICROBIOLOGICAL HAZARDS IN FOODS

Food security, as we have seen above, not only means paying attention to the reasons behind shortages in food supply, but also addressing issues like food contamination and foodborne outbreaks that indirectly contribute to food losses. A foodborne outbreak is generally defined as an incident when two or more people become sick as a result of consuming a common food or meal.[28] The symptoms and severity of food poisoning vary, depending on the nature of the hazard (i.e., biological, chemical or physical agents) and its ability to cause adverse health effects. Pathogenic bacteria are the most common cause of foodborne outbreaks and food scares around the world. More than 50% of foodborne outbreaks in the USA have been linked to bacterial infections.[29,30] In addition, microbial food contamination in the FSC that causes food losses and foodborne illnesses can result in heavy economic losses. Many studies have used cost-of-illness (COI) to estimate the economic burden of an illness on a society.[26,27,31] Such studies were also useful for making sound policy decisions about food safety interventions.[32,33]

Lake et al[31] used COI to estimate the burden of disease for certain potentially foodborne diseases (e.g., campylobacteriosis, salmonellosis, listeriosis) and their sequelae in New Zealand. The cost of foodborne infections in New Zealand is considerable and has been estimated at $86 million per year, with approximately 90% due to campylobacteriosis. In Sweden, the estimated cost of foodborne illnesses is about $171 million per year.[34] The Economic Research Service of the United States Department of Agriculture (USDA) reported that, in the USA, five foodborne pathogens (*Campylobacter, Salmonella*, *L. monocytogenes*, *E. coli* O157:H7 and *E.coli* non-O157:H7 STEC) cost $6.9 billion each year.[35] Examples of a number of bacterial foodborne outbreaks are given in Table 1. International organisations such as the FAO and the World Health Organization (WHO) have accepted the challenge to work together in order to initiate risk assessment studies of a number of pathogens in food commodities to improve consumer health and indirectly the economy.[36] Some of the most prevalent foodborne pathogens are discussed below.

Salmonella spp., one of the leading causes of foodborne outbreaks and foodborne illnesses, are a serious threat to public health worldwide. In the USA, the annual estimated economic loss was $2.4 billion in 2014 due to foodborne *Salmonella* infections.[37] *Salmonella* spp. are commonly associated with foods of animal origin (e.g., red meat, chicken and pork). The most common symptoms of salmonellosis are abdominal cramps, diarrhoea and fever.[38] Contamination by *Salmonella* can occur during production or due to inappropriate food handling during manufacturing. Data from foodborne outbreaks in the USA indicate that *Salmonella* infections were responsible for 18% of foodborne diseases in 2006,[39] but increased to 35% in 2011[40] and 38% in 2013.[41] In New Zealand, *Salmonella* spp. were respon-

Table 1: Selected Examples of Foodborne Outbreaks and Recalls Caused by Pathogenic Bacteria

Foodborne outbreak	Pathogenic bacteria	Region/Country	Initial announcement	Casualties	Estimated economic losses	Reference
Bean sprouts	*Salmonella*	USA	November 2014	115 people infected, 25 % of ill persons were hospitalized	Contaminated bean sprouts and any remaining products were destroyed	CDC[a] 2014[51]
Nut mix	*Salmonella*	New Zealand	December 2014	No illnesses were reported	Contaminated nut mixes batches were recalled	MPI[b] 2014[95]
Fresh cream	*E. coli*	New Zealand	January 2014	No illnesses were reported	8,700 bottles of fresh cream distributed to retail and foodservice outlets were recalled	MPI 2014[95]
Cheese	*L. monocytogenes*	Australia and New Zealand	March 2014	No illnesses were reported	Cheese was recalled from Australian and New Zealand supermarkets	MPI 2014[95]
Chicken	*Salmonella*	Puerto Rico and USA	March 2013	No illnesses were reported	More than 23,000 units (approximately 102,000 pounds) of contaminated chicken were recalled	CDC 2014[51]
Cheeses	*L. monocytogenes*	USA	September 2013	Six ill persons hospitalized. One death in Minnesota	All cheese products made on a specified date or earlier were recalled and destroyed	CDC 2014[51]
Sprouts	*E. coli* O104:H4	Europe and North America	May 2011	More than 4,000 persons were infected	Ban by the EU on the importation of fenugreek seeds and various other seeds, beans, and sprouts from Egypt that were the source of the sprouts responsible for the outbreaks in Germany and France	WHO[c] 2011[96]
Spinach	*E. coli* O157:H7	USA	2006	Not specified	Spinach was recalled and banned to sell	CDC 2007[97]

[a] Centers for Disease Control and Prevention; [b] Ministry for Primary Industries; [c] World Health Organization

sible for 6.6% of foodborne outbreaks in 2011 (Institute of Environmental Science and Research (ESR))[42] and increased to 10 % in 2012.[43] Despite the improvements to food safety standards in the FSC, *Salmonella* infections have continued to increase and cause considerable losses to global food safety through productivity/production losses and recalls.

Campylobacter spp. cause serious bacterial food poisoning. In the USA, *Campylobacter* is responsible for more than 600,000 illnesses that cost over $1.3 billion each year.[44] Approximately, 50% of these illnesses were attributed to poultry products such as chicken burgers and nuggets.[45] In the Netherlands, the *Campylobacter* Risk Management and Assessment (CARMA) estimated the cost of campylobacteriosis at 21 million euros annually, with 20-40% of cases attributed to contaminated poultry.[46] These bacteria infect about 1% of the population of Western Europe, and most of the infections are caused by inappropriate handling of contaminated food.[17,47] In New Zealand, campylobacteriosis has been a notifiable disease since 1980.[48] ESR reported that *Campylobacter* spp. were the most commonly identified agents in poultry and dairy outbreaks in 2013 and caused 13.3 % of the total reported foodborne disease outbreaks.[49] The economic loss due to a *Campylobacter* outbreak in August 2012 was estimated at $1.184 million.[50]

Some *E. coli* strains are pathogenic and flourish in the gut of many host species. *E. coli* O157:H7 was identified in 1982 and is now recognized as a dangerous foodborne pathogen. This, and the foodborne Shiga toxin-producing *E. coli* (STEC), have been implicated in many outbreaks around the world and the illnesses cost about $280 million annually in the USA.[35] The annual foodborne outbreaks reported by CDC[51] attributed 29 confirmed outbreaks to STEC in the USA in 2013, mostly caused by fresh produce (raw fruits and vegetables). These strains were also responsible for an outbreak in the UK in 2007 that caused 157 hospitalized cases and one death.[52] In Germany, in 2011, approximately 941 people were infected with *E. coli* O104:H4 from food.[53] In New Zealand, STEC caused two outbreaks, and 11 illnesses were reported by ESR.[54] In the case of *E. coli* O157:H7, most of the infections were from beef and minced meat.[29]

L. monocytogenes is a pathogenic bacterium that has caused a number of food outbreaks over the last decade with dairy products being the main vehicle associated with foodborne illnesses, with the capacity to affect infants and the elderly. Unlike other bacteria, infection by this bacterium has a high fatality rate of 20-30%,[55] and the annual estimated economic loss is $2.6 billion in the USA.[35] *L. monocytogenes* has been the most infamous foodborne pathogen in Australia because of its high numbers of fatal cases and substantial economic losses of $1.2 billion per year.[56] One of the most serious listeriosis outbreaks was reported in Europe in 2009-2010. The reported data showed a total of 26 people were infected, with eight fatalities in three different regions.[57] In Australia, five outbreaks caused by *L. monocytogenes* infections between the years 2001 and 2010 led to 57 cases and 14 deaths.[58] The severity of listeriosis and the difficulty of avoiding *L. monocytogenes* in the environment have highlighted the importance of improving the food safety system against *Listeria*. However, listeriosis outbreaks have recently been connected to the ability of a food to harbour viable *L. monocytogenes* throughout the manufacturing process[59] and have often been associated with inappropriate storage processes. As outlined above, the number of outbreaks caused by each pathogenic bacterium, number of reported illnesses and the associated food vehicles are well-documented in many Western countries, including New Zealand. This information has been used to estimate economic losses and highlight food safety issues in the FSC[9,60] but losses are probably underestimated because many foodborne illnesses are not reported unless they are severe. It is suggested that the pathogenic bacteria associated with foodborne outbreaks are a major cause of foodborne illnesses and will have a considerable influence on future efforts to enhance food security.

FOOD SAFETY AND FOOD SECURITY

Compromised food safety can disrupt the supply of food at any time and create the condition of food insecurity. A supply chain strategy emphasizes the management of all food safety issues that can arise due to improper transferring, handling and distribution of the product.[61,62] In fact, when managing food safety, it is essential to implement proactive strategies to minimize the probability of delivering an unsafe product. Ensuring this will reduce food scares and food losses.

Many studies have investigated different stages in the FSC where strategies for food safety have failed. A recent study investigated the occurrence of *L. monocytogenes* in 12 meat and dairy products from small-scale direct marketers in Europe.[63] The study categorized these food business operators into uncontaminated and contaminated sectors according to existing data on the occurrence of *L. monocytogenes* in each food business, which showed that *L. monocytogenes* was a common colonizer of processing environments in European food processing factories. The study revealed how environmental factors can cause cross-contamination during food production if poor hygiene practices are in place, effects that can lead to significant food losses. The influence of environmental factors on foodborne outbreaks and food security is therefore a widely debated and investigated issue.

Foodborne illnesses associated with the consumption of specific food products, such as fresh produce, cause serious issues for public health.[6,64] According to international organizations (FAO/WHO), agro-food products present the greatest concern in terms of microbiological hazards that influence public health.[65,66] In rapidly developing China, agro-food products account for more than 70% of the total food consumption.[67] This has prompted the Chinese government to establish efficient food control systems to reduce foodborne illnesses and outbreaks caused by agro-food products. The establishment of food control systems in China was delayed; however, as the various difficulties and problems in the FSC were investigated.[74] The many studies on the subject agreed; however, that lack of agro-food legislation and food safety structures were major obstacles to food security, and that in the absence of an effective food safety system, numbers of foodborne illnesses and foodborne outbreaks increase, thereby leading to food insecurity.

The production and consumption of foods, especially fresh produce and agro-food products, involves growing, transferring and handling food under conditions that vary considerably.[68] At any stage in the FSC if food safety is compromised, it can lead to food spoilage and microbial food contamination.[65,69] A research report from Canada investigated the relationship between the incidence of *Salmonella*, pathogenic *E. coli* and *Campylobacter* infections between 1992 and 2000 in two Canadian provinces, using weekly reports of confirmed cases of these three pathogens.[70] The results showed a strong association between ambient temperature and the occurrence of all three enteric pathogens. Pathogenic bacteria are present in the food processing environment because of their saprophytic lifestyles.[71] An inadequate hygiene system, poor hygiene practices and unhygienic design of equipment may cause pathogenic contamination of the food manufacturing plants.[72] This contamination can be the initial step in the transmission of pathogenic bacteria from their original source in the food crop to food processing elements[60] and, ultimately to the consumer, which can result in outbreaks of foodborne illnesses.

In order to protect consumers from microbiological and also chemical hazards, many countries have evaluated their current food control systems.[73,74] For example, two national studies were conducted, in Kuwait and the Sultanate of Oman, on the effectiveness of their current food management systems and elements of these, including the food control systems used by food producers, implementation of food legislation, food inspection protocols and the use of accredited food testing laboratories.[9,75] Both reports highlighted deficiencies in the development of standards relating to food safety and quality, and the weak food and food products inspection system at different stages during production and processing. Without addressing these problems, food losses and food insecurity are unavoidable. The impact of unclear information and knowledge among stakeholders and food handlers about the importance of food safety control can result in an ineffective food safety system.

Uncertainty in the food service sectors in the FSC and limited knowledge of food safety strategies can negatively affect food safety control during production and handling.[24,76] An inadequate system for training food handlers in food safety practices contributes to increasing incidences of microbial contamination of food.[77] With the recent increase in global food production, some international food manufacturers are relying on third parties to produce and export thousands of tonnes of food ingredients. Inadequate food safety training for these third parties handling food in the early stages of food manufacturing can lead to an increase in the number of foodborne outbreaks. Consequently, this will cause a significant loss of food products, damage the reputation of the international food manufacturing companies as food producers and, ultimately, influence food insecurity. Thus, provision of information and education about food safety and quality issues for food handlers across the FSC is important and a significant first step towards reducing food safety problems and improving food security.

It is now clearly evident that a national food safety management system is important for any country and, if compromised, can significantly increase food losses and foodborne incidents with consequent food insecurity.

IMPROVED MICROBIAL FOOD SAFETY IN THE FSC IS VITAL TO ENHANCE FOOD SECURITY

A food safety management system, therefore, is vital for ensuring the safety and quality of foods prepared for consumers. An improvement in food safety control systems can significantly reduce microbial contamination of foods throughout the FSC.[16] Therefore, it is necessary to understand how best to manage the FSC to improve microbiological food safety. Currently, different food industries apply different food safety controls in their food safety management systems, and the functioning of such systems is also variable. To ensure sustainable control of product quality it is important to have a well-managed operation at each step within the FSC. With the world facing a challenge to reduce the large amount of food produced globally that is currently lost (Figure 3), managing the different aspects of the FSC is essential.

Implicated as sources of infection that may cause microbial contamination, food outbreaks and economic losses are the primary materials for food manufacturing, such as milk, meat, fruits and vegetables (Table 1). Farmers are responsible for supplying consumers and manufacturers with the raw products for use in food manufacturing and processing. Fresh produce and raw products receive special attention because they are more likely to contain pathogenic bacteria, such as *Salmonella* spp. and *E. coli* O157:H7.[78-80] This concern has demanded the use of Good Agricultural Practices (GAP) in both crop and animal production on farms, in order to reduce the risk of microbial contamination.[81,82] Practising GAP includes all activities before and during production and at harvest. GAP also requires product inspection reports from suppliers, and these are essential records to ensure that the products are not contaminated by pathogens or toxins. Thus, applying GAP and more hygienic procedures at the farming stage is important to ensure maximum safety of the products.

However, food safety control systems are also important in other stages of the FSC to ensure the production of safe food. An ever-increasing number of food outbreaks around the world each year are linked to processed foods and cross-contamination.[83-85] Microbial contamination during food processing can result from poor application of Hazard Analysis and Critical Control Point (HACCP) principles.[86,87] In many countries, including Australia, processed and ready-to-eat meats are, potentially, a vehicle for foodborne illnesses associated with *Clostridium perfringens, Salmonella, E. coli* (EHEC) and *L. monocytogenes*.[88,89] An increase during manufacturing in the incidence of foodborne outbreaks by these bacteria[74] has resulted in the identification of specific risk profiles for these bacteria in different foods to provide the industry with risk ratings for hazardous meat and meat product combinations.[90] Such development of risk management systems and the implementation of HACCP-based food safety strategies across the FSC for different food products are essential for all countries to reduce food poisoning outbreaks and improve global food security.

Applying HACCP or a similar system of hazard control in food manufacturing business is important to control hazards and, thereby, improve the safety of food.[91,92] Table 2 lists common microbial contamination issues and the possible solutions using a food safety management system. Nevertheless, many recent studies have suggested that a combination of two or more

Table 2: Most Common Microbial Contamination Issues and the Possible Solutions Using a Food Safety Management System.

Microbial contamination issue	Frequency/impact	How to improve	References
Contamination of raw materials	• Fresh vegetable products implicated as sources of infection • Inappropriate suppliers' processes or wrong storage may cause microbial contamination	• Apply good agricultural systems and more hygienic performance in both crops and on farms • Establish effective cleaning/sanitizing programmes • Request a product inspection report from the suppliers that contains a self-evaluation document to ensure the materials were not contaminated by pathogens or toxins	Lehto et al[82]; Gustavsson et al[22]; Wu et al[98]
Risk in food packaging	• Air combined with packaging in the food supply chain is one of the major potential sources of pathogenic microorganisms	• Use appropriate air filters combined with production processes at all times that can control high-risk microbial aerosol generation • Use good hygienic practices in food processing and supply a product inspection report form to ensure the products are not contaminated by pathogens or toxins	Harris et al[99]
Risk in food refrigeration	• Inappropriate refrigeration systems can cause microbial contamination that can result in a big loss of food products	• Refrigerate food products as that should produce a safe product by reducing the temperature of the meat and vegetables to a point where the rate of growth of spoilage microorganisms is slowed down and the growth of most pathogenic microorganisms is prevented • Supply a refrigeration inspection report	James et al[100]; Sampers et al[101]; Carpentier et al[102]
Risk in transportation and food service operations	• Unsuitable and untimely transportation services can cause microbial contamination • Product handling at the end destination and/or at wrong temperatures can cause microbial contamination and food loss	• Employ time and temperature control in all stages of transportation • Use good personal hygiene • Establish effective cleaning/sanitizing programmes • Supply product inspection report forms at the products destination for all products from the initial process to the ultimate end-products	Gitahi[103]; Hassouneh et al[104]; Linton and McSwane[105]

safety control programmes, such as the International Organization for Standardization (ISO) quality management system, good manufacturing practices (GMP) and HACCP, markedly improves microbial food safety management[93,94] and, thereby reduce food contamination. Implementing one or more of these systems during food production is therefore widely recommended for food manufacturing businesses to achieve more effective food safety management to improve food security.

CONCLUSION

The threat of food insecurity is real. Many approaches have been suggested to tackle this challenge. One-third of total food produced globally never makes its way to consumers' tables due to several factors, microbial contamination being the important one. A wide variety of pathogens (e.g., *Salmonella,* pathogenic *E. coli, L. monocytogenes and Campylobacter*) are associated with foodborne illnesses and outbreaks and the consequent food and economic losses. Reducing microbial contamination and other food safety issues will significantly improve the food supply. Efficient food process controls and effective food safety systems (e.g., GAP, HACCP, ISO, GMP) are helpful in controlling microbial contaminations. Such improvements in microbial food safety practices will definitely bring additional food to the table and thereby improve food security.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. Henson S, Traill B. The demand for food safety: Market imperfections and the role of government. *Food Policy*. 1993; 18(2): 52-162. doi: 10.1016/0306-9192(93)90023-5

2. FAO. *Director-General's Report on World Food Security: A Reappraisal of the Concepts and Approaches: Item IV of the Provisional Agenda*. Rome, Italy: Food and Agriculture Organization of the United Nations; 1983: 29.

3. Kuo JC, Chen MC. Developing an advanced multi-temperature joint distribution system for the food cold chain. *Food Control*. 2010; 21(4): 559-566. doi: 10.1016/j.foodcont.2009.08.007

4. Havelaar AH, Brul S, De Jong A, De Jonge R, Zwietering MH, Ter Kuile BH. Future challenges to microbial food safety. *Int J Food Microbiol.* 2010; 139(Suppl 1): S79-S94. doi: 10.1016/j.ijfoodmicro.2009.10.015

5. Magan N, Medina A, Aldred D. Possible climate-change effects on mycotoxin contamination of food crops pre- and postharvest. *Plant Pathology.* 2011; 60(1): 150-163. doi: 10.1111/j.1365-3059.2010.02412.x

6. Liu C, Hofstra N, Franz E. Impacts of climate change on the microbial safety of pre-harvest leafy green vegetables as indicated by *Escherichia coli* O157 and *Salmonella* spp. *Int J Food Microbiol.* 2013; 163(2): 119-128. doi: 10.1016/j.ijfoodmicro.2013.02.026

7. Brown ME, Silver KC, Rajagopalan K. A city and national metric measuring isolation from the global market for food security assessment. *Applied Geography*. 2013; 38: 119-128. doi: 10.1016/j.apgeog.2012.11.015

8. Aung MM, Chang YS. Traceability in a food supply chain: Safety and quality perspectives. *Food Control*. 2014; 39: 172-184. doi: 10.1016/j.foodcont.2013.11.007

9. Al-Busaidi MA, Jukes DJ. Assessment of the food control systems in the Sultanate of Oman. *Food Control.* 2015; 51: 55-69. doi: 10.1016/j.foodcont.2014.10.039

10. van Boxstael S, Habib I, Jacxsens L, et al. Food safety issues in fresh produce: Bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain. *Food Control*. 2013; 32(1): 190-197. doi: 10.1016/j.foodcont.2012.11.038

11. Bryden WL. Mycotoxin contamination of the feed supply chain: Implications for animal productivity and feed security. *Animal Feed Science and Technology.* 2012; 173(1): 134-158. doi: 10.1016/j.anifeedsci.2011.12.014

12. Bosona T, Gebresenbet G. Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food Control*. 2013; 33(1): 32-48. doi: 10.1016/j.foodcont.2013.02.004

13. Savary S, Ficke A, Hollier CA. Impacts of global change on crop production and food security. *Global Environmental Change.* 2014; 1: 379-387. doi: 10.1007/978-94-007-5784-4_8

14. Grafton RQ, Daugbjerg C, Qureshi ME. Towards food security by 2050. *Food Sec.* 2015; 7(2): 179-183. doi: 10.1007/s12571-015-0445-x

15. Zhou J, Jin S. Safety of vegetables and the use of pesticides by farmers in China: Evidence from Zhejiang province. *Food Control.* 2009; 20(11): 1043-1048. doi: 10.1016/j.foodcont.2009.01.002

16. Manzini R, Accorsi, R. The new conceptual framework for food supply chain assessment. *J Food Eng.* 2013; 115(2): 251-263. doi: 10.1016/j.jfoodeng.2012.10.026

17. Uyttendaele M, Baert K, Ghafir Y, et al. Quantitative risk assessment of *Campylobacter* spp. in poultry based meat preparations as one of the factors to support the development of risk-based microbiological criteria in Belgium. *Int J Food Microbiol.* 2006; 111(2): 149-163. doi: 10.1016/j.ijfoodmicro.2006.05.023

18. Montanari R. Cold chain tracking: A managerial perspective.

Trends Food Sci Technol. 2008; 19(8): 425-431. doi: 10.1016/j.tifs.2008.03.009

19. Kummu M, De Moel H, Porkka M, Siebert S, Varis O, Ward PJ. Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Sci Total Environ.* 2012; 438: 477-489. doi: 10.1016/j.scitotenv.2012.08.092

20. Bond M, Meacham T, Bhunnoo R, Benton TG. Food waste within global food systems. A Global Food Security report; Swindon, UK. 2013. Web site. https://www.foodsecurity.ac.uk/. Accessed May 14 2015.

21. Buzby JC, Hyman J. Total and per capita value of food loss in the United States. *Food Policy.* 2012; 37(5): 561-570. doi: 10.1016/j.foodpol.2012.06.002

22. Gustavsson J, Cederberg C, Sonesson U, Emanuelsson A. *The Methodology of the FAO Study: "Global Food Losses and Food Waste—extent, causes and prevention"—FAO,* 2011. Gothenburg, Sweden: SIK Institutet för livsmedel och bioteknik; 2013.

23. Liu J, Lundqvist J, Weinberg J, Gustafsson J. Food losses and waste in China and their implication for water and land. *Environ Sci Technol*. 2013; 47(18): 10137-10144. doi: 10.1021/es401426b

24. FAO. *Global Food Losses and Food Waste: Extent, Causes and Prevention.* Rome, Italy: Food and Agriculture Organization of the United Nations; 2011.

25. Eriksson M, Strid I, Hansson PA. Food losses in six Swedish retail stores: Wastage of fruit and vegetables in relation to quantities delivered. *Resources, Conservation and Recycling*. 2012; 68: 14-20. doi: 10.1016/j.resconrec.2012.08.001

26. Scharff RL. Economic burden from health losses due to foodborne illness in the United States. *J Food Prot*. 2012; 75(1): 123-131. doi: 10.4315/0362-028X.JFP-11-058

27. Buzby JC, Roberts T. The economics of enteric infections: Human foodborne disease costs. *Gastroenterology*. 2009; 136(6): 1851-1862. doi: 10.1053/j.gastro.2009.01.074

28. Greig JD, Ravel A. Analysis of foodborne outbreak data reported internationally for source attribution. *Int J Food Microbiol.* 2009; 130(2): 77-87. doi: 10.1016/j.ijfoodmicro.2008.12.031

29. Newell DG, Koopmans M, Verhoef L, et al. Food-borne diseases—the challenges of 20 years ago still persist while new ones continue to emerge. *Int J Food Microbiol*. 2010; 139(Suppl 1): S3-S15. doi: 10.1016/j.ijfoodmicro.2010.01.021

30. Van Doren JM, Neil KP, Parish M, Gieraltowski L, Gould LH, Gombas KL. Foodborne illness outbreaks from microbial contaminants in spices, 1973-2010. *Food Microbiol.* 2013; 36(2): 456-464. doi: 10.1016/j.fm.2013.04.014

31. Lake RJ, Cressey PJ, Campbell DM, Oakley E. Risk ranking for foodborne microbial hazards in New Zealand: Burden of disease estimates. *Risk Analysis.* 2010; 30(5): 743-752. doi: 10.1111/j.1539-6924.2009.01269.x

32. Traill WB, Koenig A. Economic assessment of food safety standards: Costs and benefits of alternative approaches. *Food Control.* 2010; 21(12): 1611-1619. doi: 10.1016/j.foodcont.2009.06.018

33. McLinden T. A Scoping Review of Component Costs of Foodborne Illness and Analysis of the Association Between Study Methodologies and Component Costs to the Cost of a Foodborne Illness. [PhD Thesis]. Canada: University of Guelph; 2013.

34. McLinden T, Sargeant JM, Thomas MK, Papadopoulos A, Fazil A. Component costs of foodborne illness: A scoping review. *BMC Public Health.* 2014; 14(1): 509. doi: 10.1186/1471-2458-14-509

35. Hoffmann S, Batz MB, Morris Jr JG. Annual cost of illness and quality-adjusted life year losses in the United States due to 14 foodborne pathogens. *J Food Prot*. 2012; 75(7): 1292-1302.

36. FAO/WHO. Application of Risk Analysis to Food Standards Issues. Report of joint FAO/WHO expert consultation, Geneva, Switzerland, 13-17 March 1995. WHO/FNU/FOS/95.3. Geneva, Switzerland: World Health Organization; 1995.

37. Golan E. USDA Economic Research Service – Calculating the cost of foodborne illness. 2014. Web site. http://www.ers.usda.gov/amber-waves/2003-april/calculating-the-cost-of-foodborne-illness.aspx#.Vt9r5ot02Ul. Accessed April 10, 2015.

38. Mead PS, Slutsker L, Dietz V, et al. Food-related illness and death in the United States. *Emerg Infect Dis.* 1999; 5(5): 607-625. doi: 10.3201/eid0505.990502

39. Painter JA, Hoekstra RM, Ayers T, et al. Attribution of foodborne illnesses, hospitalizations, and deaths to food commodities by using outbreak data, United States, 1998-2008. *Emerg Infect Dis*. 2013; 19(3): 407. doi: 10.3201/eid1903.111866

40. Centers for Disease Control and Prevention. Surveillance for foodborne disease outbreaks United States, 2011: Annual Report. 2011. Web site. https://www.cdc.gov/foodsafety/pdfs/foodborne-disease-outbreaks-annual-report-2011-508c.pdf. Accessed August 17, 2017.

41. Centers for Disease Control and Prevention. Surveillance for foodborne disease outbreaks United States, 2013: Annual Report. 2013. Web site. https://www.cdc.gov/foodsafety/pdfs/foodborne-disease-outbreaks-annual-report-2013-508c.pdf. Ac-

cessed August 17, 2017.

42. The Institute of Environmental Science and Research Limited. Annual Report concerning foodborne disease in New Zealand. Christchurch: ESR. 2011.

43. The Institute of Environmental Science and Research Limited. Annual Report Foodborne disease in New Zealand 2012. Christchurch: ESR. 2012. Web site. http://www.foodsafety.govt.nz/elibrary/industry/2013-17-annual-report-foodeborne-disease-in-new-zealand.pdf. Accessed August 17, 2017.

44. Wesley IV, Muraoka WT. Time of entry of *Salmonella* and *Campylobacter* into the turkey brooder house. *Food Bioproc Tech.* 2011; 4(4): 616-623. doi: 10.1007/s11947-009-0190-2

45. Smith J. Campylobacter, Chicken, and the Regulatory Performance Standard. [PhD Thesis]. Manhattan, KS, USA: Kansas State University; 2013.

46. Tariq L, Haagsma J, Havelaar A. Cost of illness and disease burden in The Netherlands due to infections with Shiga toxin–producing *Escherichia coli* O157. *J Food Prot.* 2011; 74(4): 545-552. doi: 10.4315/0362-028X.JFP-10-252

47. Humphrey T, O'Brien S, Madsen M. *Campylobacters* as zoonotic pathogens: A food production perspective. *Int J Food Microbiol.* 2007; 117(3): 237-257. doi: 10.1016/j.ijfoodmicro.2007.01.006

48. Sears A, Baker MG, Wilson N, et al. Marked campylobacteriosis decline after interventions aimed at poultry, New Zealand. *Emerg Infect Dis.* 2011; 17(6): 1007-1015. doi: 10.3201/eid1706.101272

49. The Institute of Environmental Science and Research Limited. Annual Report Foodborne disease in New Zealand 2014. Christchurch: ESR. 2014.

50. Sheerin I, Bartholomew N, Brunton C. Estimated community costs of an outbreak of campylobacteriosis resulting from contamination of a public water supply in Darfield, New Zealand. *N Z Med J.* 2013; 127(1391): 13-21.

51. Centers for Disease Control and Prevention. *Surveillance for foodborne disease outbreaks United States, 2014: Annual Report*. CDC. 2014.

52. Jay MT, Cooley M, Carychao D, et al. *Escherichia coli* O157: H7 in feral swine near spinach fields and cattle, central California coast. *Emerg Infect Dis*. 2007; 13(12): 1908. doi: 10.3201/eid1312.070763

53. Rasko DA, Webster DR, Sahl JW, et al. Origins of the *E. coli* strain causing an outbreak of hemolytic–uremic syndrome in Germany. *New England Journal of Medicine.* 2011; 365(8): 709-717. doi: 10.1056/NEJMoa1106920

54. The Institute of Environmental Science and Research Limited. Annual Report Foodborne disease in New Zealand 2013. Christchurch: ESR. 2013.

55. Gillespie IA, McLauchlin J, Little CL, et al. Disease presentation in relation to infection foci for non-pregnancy-associated human listeriosis in England and Wales, 2001 to 2007. *J Clin Microbiol*. 2009; 47(10): 3301-3307. doi: 10.1128/JCM.00969-09

56. Popovic I, Heron B, Covacin C. *Listeria*: An Australian Perspective (2001-2010). *Foodborne Pathog Dis.* 2014; 11(6): 425-432. doi: 10.1089/fpd.2013.1697

57. Schoder D, Stessl B, Szakmary-Brändle K, Rossmanith P, Wagner M. Population diversity of *Listeria monocytogenes* in quargel (acid curd cheese) lots recalled during the multinational listeriosis outbreak 2009/2010. *Food Microbiol*. 2014; 39: 68-73. doi: 10.1016/j.fm.2013.11.006

58. Scallan E, Hoekstra RM, Angulo FJ, et al. Foodborne illness acquired in the United States—major pathogens. *Emerg Infect Dis*. 2011; 17(7): 7-15. doi: 10.3201/eid1701.P11101

59. Hoelzer K, Pouillot R, Gallagher D, Silverman MB, Kause J, Dennis S. Estimation of *Listeria monocytogenes* transfer coefficients and efficacy of bacterial removal through cleaning and sanitation. *Int J Food Microbiol.* 2012; 157(2): 267-277. doi: 10.1016/j.ijfoodmicro.2012.05.019

60. Alali WQ, Schaffner DW. Relationship between *Listeria monocytogenes* and *Listeria* spp. in seafood processing plants. *J Food Prot.* 2013; 76(7): 1279-1282. doi: 10.4315/0362-028X.JFP-13-030

61. Xuexin L. Designing and establishing food logistics safety system in China. Paper presented at: *E-Business and E-Government* (ICEE), 2011 International Conference; 2011: 1-5

62. Giacometti F, Serraino A, Finazzi G, et al. Sale of raw milk in northern Italy: Food safety implications and comparison of different analytical methodologies for detection of foodborne pathogens. *Foodborne Pathog Dis*. 2012; 9(4): 293-297. doi: 10.1089/fpd.2011.1052

63. Muhterem-Uyar M, Dalmasso M, Bolocan AS, et al. Environmental sampling for *Listeria monocytogenes* control in food processing facilities reveals three contamination scenarios. *Food Control*. 2015; 51: 94-107. doi: 10.1016/j.foodcont.2014.10.042

64. Ilic S, Odomeru J, LeJeune JT. *Coliforms* and prevalence of *Escherichia coli* and foodborne pathogens on minimally processed spinach in two packing plants. *J Food Prot*. 2008; 71(12): 2398-2403.

65. Huang GQ, Lau JS, Mak KL. The impacts of sharing pro-

duction information on supply chain dynamics: A review of the literature. *Int J Prod Res*. 2003; 41(7): 1483-1517. doi: 10.1080/0020754031000069625

66. Naumova EN, Jagai JS, Matyas B, DeMaria A, MacNeill IB, Griffiths JK. Seasonality in six enterically transmitted diseases and ambient temperature. *Epidemiol Infect*. 2007; 135(02): 281-292. doi: 10.1017/S0950268806006698

67. Jin S, Zhou J, Ye J. Adoption of HACCP system in the Chinese food industry: A comparative analysis. *Food Control*. 2008; 19(8): 823-828. doi: 10.1016/j.foodcont.2008.01.008

68. Fraser ED. Food system vulnerability: Using past famines to help understand how food systems may adapt to climate change. *Ecological Complexity*. 2006; 3(4): 328-335. doi: 10.1016/j.ecocom.2007.02.006

69. McMichael AJ, Woodruff RE. Climate change and human health. In: Oliver JE, eds. *Encyclopedia of World Climatology*. Netherlands: Springer; 2005: 209-213

70. Fleury M, Charron DF, Holt JD, Allen OB, Maarouf AR. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. *Int J Biometeorol*. 2006; 50(6): 385-391. doi: 10.1007/s00484-006-0028-9

71. Ferreira V, Wiedmann M, Teixeira P, Stasiewicz MJ. *Listeria monocytogenes* persistence in food-associated environments: epidemiology, strain characteristics, and implications for public health. *J Food Prot*. 2004; 77(1): 150-170. doi: 10.4315/0362-028X.JFP-13-150

72. Almeida G, Magalhães R, Carneiro L, et al. Foci of contamination of *Listeria monocytogenes* in different cheese processing plants. *Int J Food Microbiol*. 2013; 167(3): 303-309. doi: 10.1016/j.ijfoodmicro.2013.09.006

73. Alomirah H, Al-Zenki S, Sawaya WN, Hussain A, Omair A. Assessment of the food control system in the state of Kuwait. *Food Control*. 2010; 21(4): 496-504; doi: 10.1016/j.foodcont.2009.07.015

74. Yang L, Qian Y, Chen C, Wang F. Assessing the establishment of agro-food control systems based on a relevant officials' survey in China. *Food Control*. 2012; 26(2): 223-230. doi: 10.1016/j.foodcont.2012.01.048

75. Alomirah HF, Al-Zenki SF, Sawaya WN, et al. Assessment of the food control system in the State of Kuwait. *Food Control*. 2010; 21(4): 496-504. doi: 10.1016/j.foodcont.2009.07.015

76. Wu SL. Factors influencing the implementation of food safety control systems in Taiwanese international tourist hotels. *Food Control*. 2012; 28(2): 265-272. doi: 10.1016/j.foodcont.2012.05.038

77. Chapman B, Eversley T, Fillion K, MacLaurin T, Powell D. Assessment of food safety practices of food service food handlers (risk assessment data): Testing a communication intervention (evaluation of tools). *J Food Prot*. 2010; 73(6): 1101-1107. doi: 10.4315/0362-028X-73.6.1101

78. Al-Lahham O, El Assi NM, Fayyad M. Impact of treated wastewater irrigation on quality attributes and contamination of tomato fruit. *Agricultural Water Management*. 2003; 61(1): 51-62. doi: 10.1016/S0378-3774(02)00173-7

79. Khan AA, Husain Q. Potential of plant polyphenol oxidases in the decolorization and removal of textile and non-textile dyes. *J Environ Sci (China)*. 2007; 19(4): 396-402. doi: 10.1016/S1001-0742(07)60066-7

80. Girones R, Ferrús MA, Alonso JL, et al. Molecular detection of pathogens in water-the pros and cons of molecular techniques. *Water Research*. 2010; 44(15): 4325-4339. doi: 10.1016/j.watres.2010.06.030

81. Little CL, Gillespie IA. Prepared salads and public health. *J Appl Microbiol*. 2008; 105(6): 1729-1743. doi: 10.1111/j.1365-2672.2008.03801.x

82. Lehto M, Kuisma R, Määttä J, Kymäläinen HR, Mäki M. Hygienic level and surface contamination in fresh-cut vegetable production plants. *Food Control*. 2011; 22(3): 469-475. doi: 10.1016/j.foodcont.2010.09.029

83. Olsen SJ, Patrick M, Hunter SB, et al. Multistate outbreak of *Listeria monocytogenes* infection linked to delicatessen turkey meat. *Clin Infect Dis*. 2005; 40(7): 962-967. doi: 10.1086/428575

84. Pointon A, Jenson I, Jordan D, Vanderlinde P, Slade J, Sumner J. A risk profile of the Australian red meat industry: Approach and management. *Food Control*. 2006; 17(9): 712-718. doi: 10.1016/j.foodcont.2005.04.008

85. Ross T, Rasmussen S, Fazil A, Paoli G, Sumner J. Quantitative risk assessment of *Listeria monocytogenes* in ready-to-eat meats in Australia. *Int J Food Microbiol*. 2009; 131(2): 128-137. doi: 10.1016/j.ijfoodmicro.2009.02.007

86. Sampers I, Habib I, De Zutter L, Dumoulin A, Uyttendaele M. Survival of *Campylobacter* spp. in poultry meat preparations subjected to freezing, refrigeration, minor salt concentration, and heat treatment. *Int J Food Microbiol*. 2010; 137(2): 147-153. doi: 10.1016/j.ijfoodmicro.2009.11.013

87. Capps O, Colin-Castillo S, Hernandez MA. Do marketing margins change with food scares? Examining the effects of food recalls and disease outbreaks in the US Red Meat Industry. *Agribusiness*. 2013; 29(4): 426-454. doi: 10.1002/agr.21340

88. Sim J, Hood D, Finnie L, et al. Series of incidents of *Listeria monocytogenes* non-invasive febrile gastroenteritis involving ready-to-eat meats. *Lett Appl Microbiol*. 2002; 35(5): 409-413. doi: 10.1046/j.1472-765X.2002.01207.x

89. De Valk H, Vaillant V, Jacquet C, et al. Two consecutive nationwide outbreaks of listeriosis in France, October 1999–February 2000. *Am J Epidemiol*. 2001; 154(10): 944-950. doi: 10.1093/aje/154.10.944

90. Sumner J, Ross T, Jenson I, Pointon A. A risk microbiological profile of the Australian red meat industry: Risk ratings of hazard–product pairings. *Int J Food Microbiol*. 2005; 105(2): 221-232. doi: 10.1016/j.ijfoodmicro.2005.03.016

91. Mantovanelli A, Marino M, Comi G, Vallavanti W, Dolzani L. Use of microbial analysis to test HACCP systems in food industries. Italy: Industrie Alimentari; 2001.

92. Mortimore S. How to make HACCP really work in practice? *Food Control*. 2001; 12(4): 209-215. doi: 10.1016/S0956-7135(01)00017-2

93. Arvanitoyannis IS, Sakkomitrou M. Quality management, ISO 22000: 2005 and HACCP in fruit processing and packaging. In: Siddiq M, ed. *Tropical and Subtropical Fruits: Postharvest Physiology, Processing and Packaging*. Oxford, UK: Wiley-Blackwell; 2012: 97-114.

94. Afoakwa EO, Mensah-Brow H, Crentsil GK, Frimpong K, Asante F. Application of ISO 22000 in comparison with HACCP on industrial processing of milk chocolate. *International Food Research Journal*. 2013; 20(4): 1771-1781.

95. Ministry for Primary Industries. Food Recalls 2014. https://www.mpi.govt.nz/food-safety/food-safety-for-consumers/food-recalls/. Accessed May 6, 2015.

96. World Health Organization. World health statistics 2010. Geneva: WHO; 2011. Web site. http://www.who.int/whosis/whostat/2010/en/. Accessed August 17, 2017.

97. Centers for Disease Control and Prevention. *Food Net 2007 Surveillance Report*. Atlanta, GA: US Department of Health and Human Services, CDC; 2007.

98. Wu W, Zhao S, Mao Y, Fang Z, Lu X, Zeng L. A sensitive lateral flow biosensor for *Escherichia coli* O157: H7 detection based on aptamer mediated strand displacement amplification. *Anal Chim Acta*. 2014; 861: 62-68. doi: 10.1016/j.aca.2014.12.041

99. Harris JK, Mansour R, Choucair B, et al. Health department use of social media to identify foodborne illness – Chicago, Illinois, 2013-2014. *MMWR Morb Mortal Wkly Rep*. 2014; 63(32): 681-685.

100. James C, Vincent C, de Andrade Lima TI, James SJ. The primary chilling of poultry carcasses – a review. *International Journal of Refrigeration*. 2006; 29(6): 847-862. doi: 10.1016/j.ijrefrig.2005.08.003

101. Sampers I, Habib I, Berkvens D, Dumoulin A, De Zutter L, Uyttendaele M. Processing practices contributing to *Campylobacter* contamination in Belgian chicken meat preparations. *Int J Food Microbiol*. 2008; 128(2): 297-303. doi: 10.1016/j.ijfoodmicro.2008.08.024

102. Carpentier B, Lagendijk E, Chassaing D, Rosset P, Morelli E, Noël V. Factors impacting microbial load of food refrigeration equipment. *Food Control*. 2012; 25(1): 254-259. doi: 10.1016/j.foodcont.2011.10.051

103. Gitahi MG. Microbial Quality, Strain Distribution and Enterotoxigenicity of Selected Food Borne Pathogens in Relation to the Hygienic Practices in Industrial Area, Nairobi, Kenya [MSc Thesis]. Nairobi, Kenya: University of Nairobi; 2012.

104. Hassouneh I, Radwan A, Serra T, Gil JM. Food scare crises and developing countries: The impact of avian influenza on vertical price transmission in the Egyptian poultry sector. *Food Policy*. 2012; 37(3): 264-274. doi: 10.1016/j.foodpol.2012.02.012

105. Linton RH, McSwane DZ. Food safety post-processing: Transportation, supermarkets, and restaurants. In: Potter JGME, ed. *Foodborne Infections and Intoxications*. 4th ed. San Diego; CA, USA: Academic Press; 2013: 479-496.