A Comparative Study of Canadian and International Food Safety Systems and how to improve Canadians access to safe food

DALHOUSIE UNIVERSITY
FACULTY OF AGRICULTURE

Agri-Food Analytics Lab

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Executive Summary

In January 2019, the Safe Food for Canadians Act/Safe Food for Canadians Regulations (*heretofore identified as SFCR*) came into force across Canada, and brought a more streamlined process to food safety practice in Canada. Food trade and production processes have evolved rapidly in recent decades, as Canada both imports and exports food products, therefore it is critically important to remain aware of the latest advances responding to a range of challenges and opportunities in the food safety value chain. Looking through the optics of the recent SFCR framework, this report places the spotlight on leading domestic and international research and practices.

By shedding light on new research, we also draw attention to international developments that are noteworthy, and place those in context as to how new Canadian food safety policy and regulation can be further advanced. The report will benchmark Canada through a comparative study of food safety best practices by juxtaposing i. stated aspirations with, ii. actual performance in leading Organization for Economic Cooperation and Development (OECD) jurisdictions. Comparing standards, acts and regulations in jurisdictions (e.g. organizational processes, management controls, education, technologies, and coordination), and at the supra-national level, such as the Global Food Safety Initiative (GFSI), with actual, current levels of performance will gain insight to critical considerations for Canadian food safety practices leading the coming decade of practice.

The recommendations at the end of this report outline beneficial enhancements to the vitality of the Canadian food industry and for general public health. With a view on food safety, five over-arching sub-sections have been identified for focus. They are:

1. Food Distribution, Traceability and Supply Chains;
2. Inspection;
3. Digitization, E-commerce, Data Science, and Predictive Analytics;
4. Labelling and Packaging; and
5. Risk and Preventive Controls Management.

The focus on these 5 areas is set in the context of Canada's SFCR evolution within the outcomes-based approach of the Act and Regulations. The ultimate goal to building a robust perspective upon which Canada will be able to take notice of, and be future-ready in relation to changing trade, technology and business practices related to food safety.

The Canadian Food Inspection Agency (CFIA) has to be acknowledged as one of a few trusted partners in this endeavor.

Project Team

The Agri-Food Analytics Lab (AAL) – an independent knowledge hub headquartered at Dalhousie University on Canada's east coast – uses advanced agri-food analytics to help the industry explore, learn, innovate, commercialize; and to improve food quality, security, sustainability, appreciation, and 'healthfulness'.

Drawing on diverse, deep, and broad expertise from across agriculture and aquaculture, oceanography, engineering, computer science, philosophy, and sociology, the AAL collects, monitors, and continuously mines agri-food data to improve distribution of healthy, affordable and sustainable food.

Vision and mission

The Agri-Food Analytics Lab (AAL) aims to understand the future of agri-food systems through analytics. The bilingual institute provides a global knowledge hub and space for sharing intelligence, research and learning on food security, agriculture, aquaculture, agri-business and social aspects of food.

Project Lead:

Dr. Sylvain Charlebois

Professor, Food Distribution and Policy, Faculty of Management
Professor, Faculty of Agriculture
Senior Director, Agri-food Analytics Lab
Dalhousie University

Research Assistant:

Mark Juhasz

Editor:

Susan Tremills

Introduction

Objectively, how does Canada's SFCR relate to international developments in food safety regulation, practice, methodologies and management systems. There are many points of reference at the national and international level to compare with, including the International Standards Organization (ISO) 22000 system of standards for interactive communication, system management and prerequisite programs; Hazard Analysis and Critical Control Points (HACCP), the Codex Alimentarius, and the GFSI. How does European Union EU Good Manufacturing Practice apply to food safety regulations and trade today?

A critically important sentiment, especially within the current climate of a global pandemic as a result of COVID-19, is food safety regulators want to know if their current domestic policies and regulations are adequate to support food safety risk intelligence efforts (Charlebois and Le Vallee, 2014). This report provides an updated scan of leading international practices to benchmark Canada's newest framework to continue informing food safety system design, adaptation, and implementation given new technological, managerial and social realities.

A significant set of examples in this report come from leading European jurisdictions, and their developments in food safety. The EU parliament create legislation in the form of directives and regulations, many of which have become mandatory for member states, and in turn are incorporated into individual countries national legislation. The EU parliament, informed by the European Food Safety Authority (EFSA), also needs to face the realities of member state legislation and preventative controls, as long as trade is not impacted between EU countries. For example, in the UK, the Food Standards Agency is an independent government department responsible for food safety and hygiene, and works with businesses and local authorities on awareness and enforcement. The UK government, or any other, need to balance the demands, dynamics and conditions of businesses and consumers in their own country, to commitments to international trade agreements, such as the with USA.

In the USA, the Food Safety Modernization Act (FSMA), established in 2011, is a relatively new national framework, and involved a major shift from response and containment, to the new mantra of prevention, risk assessment and proactive management. The act gives the USFDA (United States Food and Drug Administration) authority to regulate foods grown, processed and harvested. In turn, food businesses are adopting food safety management systems (FSMS), and all the coordination, training, and application that implies.

Amidst these international developments, Canada's 2019 SFCR can be seen better in perspective for this report. How is Canadian food inspection comparing to international leading practices? What protocols are being generated by government regulation and/or private sector responses and innovations? How are regional prevention controls approached, encouraged and monitored for effectiveness at the provincial or municipal level?

A Government of Canada publication on food safety (2018) recognizes that consumer confidence and food safety are very important to the success of food businesses, and that the responsibility in the production, processing, import, export, treatment, preserving, grading, packaging, and labelling of food cannot be compromised. Canadian food industry leaders also realize that the complexity of the global food system, with many food products crossing borders, and processed foods, with many ingredients, require a range of methods and means by which to ensure the greatest amount of adaptive oversight as possible. The Canadian Food Inspection Agency (CFIA) has a central role in this as a responsive, alert and innovative federal regulator (GoC, 2018:1). With the SFCR, 14 sets of previous food regulations were consolidated into the SFCR to improve consistency across all food types, and between food businesses. The SFCR also has an eye to internationally recognized standards (such as the Codex Alimentarius). The SFCR builds on the spirit of risk management, education, proactive training, and accurate measurement. Across the complexity of food supply chains in Canada, the SFCR also regulates the requirements of licensing for food businesses. In regards to prevention, a Preventive Control Plan (PCP) details how risks to food are identified and controlled. The SFCR includes measures on traceability, based in part on the Codex Alimentarius, for trading food across the supply chain, from immediate customers to initial suppliers. Commodity-specific requirements exist for sub-sectors such as dairy, meats or produce.

Considering this brief overview of the SFCR in the Canadian context, the following report will place a spotlight on examples of recent research into food safety internationally, from leading scientific research. Both the macro, and local trends emerging will more clearly identify recurring themes, and how broader food industry realities, such as growing recognition of sustainability pressures on resources for food production (e.g. climate change, habitat pressure on biodiversity, weather patterns, the current COVID-19 pandemic) will in turn impact how food safety regulation and industry respond.

METHODOLOGY

A base environmental scan of the SFCA-SFCR was conducted to understand the changes to food inspection and safety in Canada. In addition, a base environmental scan was also conducted of recent developments and innovations in USA-based food safety, including the recent introduction of the Food Safety Modernization Act; of the European Union's European Food Safety Authority, and of the Global Food Safety Initiative, ISO and HACCP. This combination of location specific and international standards formed the basis for a literature review of the leading scientific, peer-reviewed journals in food safety, these are; i. the Journal of Food Policy; ii. the Journal of Food Protection; iii. the Journal of Food Safety; iv. the Journal of Food Control; and v. the Comprehensive Review in Food Science and Food Safety. The past 4 years of articles in these journals was scanned based on the 5 sub-sections of this report, which are:

1. Food Distribution, Traceability and Supply Chains;
2. Inspection;
3. Digitization, E-commerce, Data Science, and Predictive Analytics;
4. Labelling and Packaging; and

5. Risk and Preventive Controls Management.

Apart from reference to leading international food safety standards, such as the GFSI, HACCP, ISO, and reference to food safety innovations in the USA, and the European Union, the methodology also draws on examples and case studies from the literature review from different parts of the world, including Latin America and Asia, but primarily as illustrative examples of food safety innovation.

Sectional Key Theme Tables

In each of the five sections of this report, a key theme table was created. Based on the environmental scan, and literature review in each respective section, there were three factors used to build the table; i. the leading theme(s) determined; ii. leading jurisdictions where the theme is being implemented, and; iii. Complexity of Use/Transfer to Canada.

In regards to i. the leading theme, there is some degree of aggregation from the limited scope of the literature review over the past 4 years of articles. Some themes have been grouped together. In regards to ii. the leading jurisdictions where the theme is being implemented, this is based on the base scan from the literature, and general research acquired by the project team.

Finally, in regards to iii. Complexity of Use/Transfer to Canada, a scale from 1 to 5 has been developed, and in consideration to the applicability of this theme/new innovation-application to the Canadian context, especially in light of the new SFCA-SFCR. From a base environmental scan of the Canadian food industry, and food safety, including consideration of Canada's trade partners, technological capacity, advancement of the application internationally and compatibility with our existing regulatory frameworks, a 1 (out of 5) is given, if use of the application can be considered very easy. Alternately, on the other end of the scale, a 5 (out of 5) is given if the complexity, feasibility and transfer of use to Canada is likely to be complex, difficult and challenging. It is important to mention and note that this table is intended as a rough heuristic and tool for general consideration from a limited literature review, not as a definitive standard.

1. Food Trade, Distribution, Traceability and Supply Chains

The focus of this section, especially now that food products are traded globally so extensively, is to acknowledge the risks associated with food mislabelling, (and leading practices internationally to ensure food safety). This section also provides insight on recent developments in policies, practices, and frameworks on what trade, distribution, traceability and supply chain protocols have on food safety.

Food businesses (and their suppliers) want to know the food safety practices of supply chain partners up- and down- stream, including how is this being coordinated in leading jurisdictions, and at the level of international coordination. In the literature review for this section, we examine a combination of: specific regulations and policies at the national level; regulations for importing/exporting (and required documentation on traceability); authority and responsibility protocols; regulations and voluntary measures; tracking and registration leading practices; international standards and benchmarks; electronic and digital tracking tools; and information management examples from the European Union, the United States, and Canada.

Important considerations for food supply chains related to food safety, especially in a post-pandemic era, include the sustainability metrics in food trade (Greenhouse gas [GHG] emissions, carbon footprint, and security of supply chains amid the risks of national supply lockdowns). How will international and national regulations change in relation to food safety protocols, guidelines and frameworks, and how will governments intervene in relation to the initiatives of the private sector?

1.1 Regulatory Standards (National and International), Oversight, Compliance, FSMS

1.1.1 Food Fraud, Compliance and Traceability in FSMS (Food Safety Management Systems)

Associated with some of the risks of international food trade regimes, there is also the spectre of food fraud. Cadieux et al (2019) state that the 'food industry has a different perspective from that of the Government of Canada and may provide valuable input, claiming to have better awareness of food fraud hazards encountered on a regular basis'. Food industry stakeholders should be central to governmental food fraud prevention strategies. Government, academia and food industry leaders together can create more efficient detection methods. According to the Grocery Manufacturers Association, food fraud costs the industry up to $15 billion annually (Cadieux et al, 2019). Food fraud is ultimately also a food safety consideration. Undeclared ingredients can find their way into products that can be dangerous sources of allergens, and in turn a broader public health risk. Critics point to the current lack of a coherent penalty as an ineffective deterrent, given the economic gains for violators, of using fraudulent food

alternatives. For this reason, the SFCR should consider how food fraud monitoring systems are established nationally, and in relation to international trade good.

The risks of food fraud are also handled differently by the size and scale of a food operation, whether in Canada, or internationally. For small and medium sized enterprises (SMEs), of which in Canada, they are the majority, traceability, food safety management systems (FSMS), quality management and tracking are important requirements for business trust, and regulatory compliance. Dzwolak, W, (2016) looked at how 'traceability is a very important component of controlling non-conforming products in FSMS, and quality management systems to ensure safety and public health for consumers, and linked these systems to certification protocols as an overarching framework within jurisdictions, wherever they are. Whether SMEs, medium sized or large food operators are required by regulation to meet certain protocols, compliance with leading food safety practices in international trading regimes means working within the boundaries defined by contractual, social and rapidly evolving trade standards. From a different perspective, Manning (2020), outlines how compliance-based food trade systems can at once stifle innovation, while also, if implemented effectively, promote positive food safety trading regimes, and greater trust. Alternately, Manning outlines building organizational cultures of integrity-based food trade and safety management, with early warning systems to pinpoint deviation based on a strong ethical supply chain that builds trust and cultural maturity. Critically viewed however, this model might be more effective at the regional level for the immediate future in the Canadian context.

1.1.2 Case studies: HACCP + potential hazard identification in food supply chains

HACCP (Hazard Analysis and Critical Control Points) has use application since the 1960s, introduced by Pillsbury, NASA, and the Natick Laboratories for the U.S. space program. It was adopted by the Codex Alimentarius Commission in 1993 as an Annex of the 'Recommended International Code of Practice – General Principles of Food Hygiene'. While HACCP can be used throughout the food supply chain, its application is product specific. HACCP remains an important tool and relevant to food products caught, grown, harvested and traded internationally. For example, Chen, R et al (2018) studied whether compliance with HACCP had an impact on seafood imports to the USA. Based on the results, the authors found no impact of the tool on trade flows into the country because HACCP is not necessarily a protectionist measure, and because consumers and retailers may have minimal response to the implications of HACCP's use for food safety.

A recent study by Park J.M. et al (2020) examined the concern over safety of food information in distribution channels, with questionable or fraudulent food ingredients. Hazards such as microbial contamination or food fraud need to be identified post-production. The study builds on recognition that post-production logistics centres, or ports of entry (in this case into Canadian markets) need to be able to proactively test for food integrity before shipping to domestic points-of-sale.

1.2 New Tech Applications (Cold chains, Blockchain, DNA coding, Trust)

Recent technological developments in tracking and monitoring food trade supply chains are extensive. An example of this is with cold chains, which in essence are responsible for keeping perishable foods frozen until they reach their final retail markets. While refrigeration is most likely an energy intensive activity, the need for food supply chains to reduce product waste and ensure food safety to end markets is in line with current global food security (Badia-Melis, R. et al, 2018). Leading cold supply chain logistics companies use applications such as computational fluid dynamics systems that can correct inefficiencies at pre-cooling stages. Radio frequency, wireless sensors, and thermal imaging neural networks round out the technological advancements to keep food frozen to ensure greater food safety of shipped products.

Drawing an example from the seafood supply chain, Shehata, H.R. et al (2018), examined the use of DNA barcoding to speciate finfish fillets sold and consumed in Canada. The authors assess whether the CFIA's use of this technology as a regulatory tool is truly effective. From a sample of 354 finfish products collected across Canada between 2013 and 2016, there was an overall success rate of 93%, with mislabels affecting 14%. From a food safety perspective, some consumers may have allergies to certain types of finfish even though allergens are not declared by species. Individuals allergic to specific species of fish are usually advised to avoid fish altogether. Shehata, H.R. et al also noted that there may not exist DNA barcodes for some types of finfish, and furthermore, that mis-labelling leads to lost consumer trust in the safety of seafood products, undermining efforts toward sustainable marine ecosystem management of wild-caught fisheries. Fraud may in this context be a more important issue with regards to species mislabelling (consumers unfairly paying the price of a more expensive species).

Another technological development making its way into food supply chains, and which can lend itself to food safety is blockchain. Food traceability is very challenging for companies, retailers, and government regulating authorities because of the myriad modifications that can take place with ingredients, bacteria or viruses for example. While blockchain may still be relatively new as an application, this technology may become more integrated into food tracking systems which the CFIA should remain aware of. Blockchain algorithms have the potential to store data and enable quick tacking across many supply chain processes steps, giving stakeholders ability to monitor much faster. One possibility from a recent study is to use blockchain to detect food safety parameters, such as microbial infestation or contamination, such as mold toxin, heavy metals, pesticides or allergens. Blockchain can also indicate concerns over geographic origin or biological and chemical identity and methods of production (Creydt, M, M. Fischer, 2019). Combining blockchain, with for example, data points tracking with an Internet-of-Things, especially in food trade would be a powerful framework in revolutionizing the food industry. Indeed, some retailers are already beginning to make demands and give incentives to their supply chain partners (Creydt, M., M. Fischer, 2019).

Another example is TrustTracker, examined by Macready, A et al (2020), that involved an online survey in 5 European countries, to examine consumer trust in food chain companies, and its

impact on confidence in food technologies. The model looks at social trust, beliefs of trust-worthiness, overall trust in food chain actors, and confidence in the supply of food products. The results indicate that beliefs about openness of food manufacturers are strongly related to consumer confidence, with differences in trust and confidence between nations. The study highlights the need for the ultimate need to have consumers trust the applications and technologies being used or considered throughout food supply chains, and their relation to food safety, and whether consumers will buy products using a range of technological applications.

1.3 Examples of Trade and Supply Chain Issues in Sub-sectors

1.3.1 International Trade in Dairy Products (EU, raw cheese, compliance)

One of the international products with significant scrutiny are dairy products, especially with new trade agreements between Canada and the EU. Dairy products imported to Canada may have supply chain and traceability concerns over microbiological hazards specific to the SFCR. A recent study by Van Asselt, E.D. et al (2017) notes that realities such as climate change, and changing consumer demands will place the dairy supply chain under further intensification. Increased livestock production may result in animal diseases, antibiotic use and increased pressure on dairy livestock feed. These will also have implications for sustainability and animal welfare in the dairy industry.

As is evident from COVID-19, zoonotic disease is an important concern in animal-to-human disease transmission. Brucellosis is example of a community transmitted disease through the consumption of unpasteurized milk and dairy products (and is one of the most common zoonoses in the world). How might Canada develop the scientific methods to test for this disease, given that considerable numbers of human cases are still reported annually (Jansen, W et al, 2019).

For example, artisan and raw milk-based cheeses, remain a leading niche category for imports. These products also face stringent food safety scrutiny. In the USA, the relatively new FSMA have created unprecedented regulatory challenges for cheese makers (Limoges, M., C. Donnelly, 2019).

1.3.2 Beef, grains, farmers markets

Consumers are now able to use QR codes to trace products. Regarding meat, there is concern over food traceability. Spence, M. et al (2018) note how this has placed pressure on food companies to be able to demonstrate safety in their traceability. QR codes (quick response), printed on product packaging, helps consumers access information from their phones. A post-COVID environment, (based on the experience of African swine flu in China, consumption of meats, imported or traded across distances), will require all regulators and consumers, to remain vigilant.

Alternately to beef, attention has also been drawn to glyphosate residues in grains. Scientists have studied the potential risks associated with glyphosate, which is an active ingredient in herbicides utilized for weed control and drying cereals and grain crops. While a study by Xu et al (2019) note that overall glyphosate residues are below current maximum residue limits, more studies are needed to understand any health concerns related to exposure, consumption, and impact on food safety.

Finally, while not international in nature, traceability considerations need to be drawn to the context of farmers markets, which have grown in popularity in the past decade in particular in Canada, and food safety needs to be part of their future development. In Ontario for example, farmers markets have developed a detailed food safety manual for market managers and vendors, even though food safety training nor certification are required. Young, I et al. (2020), outline how future outreach efforts to improve behaviour should target both vendors and market managers alike.

1.4 Summary and Key Observations - Section 1 – Top leading themes

Leading Themes	**Leading Jurisdictions**	**Complexity of Use/Transfer to Canada – 1 (easiest) to 5 (most complex and difficult)**
Compliance-based food trade (HACCP, GFSI, others) (Manning, 2020; Chen et al, 2018)	International	3, based on the outline of specific international standards that Canadian food businesses, in coordination with the CFIA, can follow. Transferability likely dependent on size of food business
Tracking systems (DNA barcoding; blockchain; QR codes) (Shehata et al, 2018; many authors)	National to International	4, dependent on the novelty of the tracking system. DNA barcoding more specific to particular sub-sectors, such as fisheries. Blockchain still relatively new with logistical, coordination challenges, but eventual advantage of cost and time effectiveness
Cold chains (many authors)	International to national	3, depending on trade routes for Canadian food businesses, and where cold storage is critical to food safety and perishability.
Zoonotic disease (many authors, many types of disease, such as Brucellosis)	International	5, more important now then ever in light of the COVID-19 pandemic. Regulatory and consumer concern over animal-to-human transmission of disease and risk.

At the time of this final report, most of the world, including Canada, is under significant travel restrictions, however food products are still largely moving across borders. While it is speculative to imagine what the mid- to long- term implications will be for food trade, most of the leading scientific literature of the past few years on trade, supply chains and food safety have attempted in some form or other to be able to manage and come to terms with the complexity and variety of regulations, frameworks, and risks associated with a complex international supply chain.

Many food business operators have a first response to cases of fraud and adulteration in their supply chains, or become aware of substituted ingredients. Food fraud is a multi-billion-dollar international phenomenon, and violators, unfortunately, are motivated by the prospects of significant profit undetected. The research indicates that addressing food fraud, and its associated implications for food safety, will require the coordination beyond anyone national framework, such as the SFCR, the USA's Food Safety Modernization Act, the EU's European Food Safety Authority, or the Global Food Safety Initiative. The private sector, the scientific community and public regulators will need to coordinate information and responses rapidly. We also are learning that in economies where food SMEs dominate, as in Canada, that the cost of compliance, to meet international trade opportunities, can be prohibitive, and these need to be continually reviewed by all stakeholders. Fortunately, we are seeing the rapid development of tools such as advanced monitoring of cold supply chains, DNA barcoding, blockchain technology, and the 'TrustTracker', as new methods by which to more effectively facilitate trade while also closely ensuring food safety. Certain sub-sectors of the food economy, such as the trade in animal products (e.g. dairy and meats), may face even greater scrutiny, for the potential risk of zoonotic disease or infection, and government regulators can be extra vigilant, but also cooperative with these sub-sectors.

2. Inspection

In this section, an examination is conducted of leading studies on best practices and emerging trends in food inspection, including the motivating factors of inspectors, how decisions are made, how this impacts food businesses, and the overall value or concern of these new developments.

2.1 Government vs. 3rd party inspection systems

A recent study from the United Kingdom (UK) illustrated the relationship between the degree of trained food hygiene inspection, compliance with those food hygiene laws, microbial contamination, and outbreaks of foodborne illness. In the UK, a *Food Law Codes of Practice* was established. The study indicated that regular, visual inspections, done by trained inspectors is an important measure in reducing outbreaks. The analysis suggests an important link in the benefit of vigilant surveillance, and stronger government policy on food hygiene. The UK study also goes beyond the point of inspection alone, and further advocates for a multi-pronged approach of

data sharing across the supply chain, from farm to fork, drawing attention to the successful *Campylobacter initiative*. The Fleetwood (2019) study emphasizes the idea that more eyes and minds 'on-deck' make for a more robust system of awareness, compliance and monitoring what back and re-examine evidence-based protocols and government actions.

2.1.1 Difference and Alignment: Government and 3rd party inspections

A study by Turku, M et al (2018) investigated whether government inspections and 3rd party audits in food establishments were in alignment by surveying both inspectors and food business operator's perception of officials. The results showed that all those surveyed recognized non-compliance, non-conformity, and discrepancy between the findings of government officials. The question of the study focused on weighing the benefits of 3rd party auditors with that of government inspections within a food safety management system (FSMS). The study did highlight that self-checking categories, such as maintenance of premises and sanitation lags can have serious consequences on food safety (Turku, M. et al, 2018).

Further attention to examinations of government vs. 3rd party inspections was conducted in a study by Shang, X. G, and T. Tonsor (2019). The authors note that considering the increasing trend of food take-out, it is valuable consideration to look at corresponding data, and in future research, to understand market segments and recalls at less aggregated levels than national levels to enhance demand impact, and improve policy and industry decisions. The premise being that in different regions, food recalls will have different impacts, whether in Canada, or the USA. Consumer response to an impact can also be varied, depending on the consumption dynamics in a region, whether it is more urban, suburban or rural.

Regarding government inspection, in the USA for example, the immense challenge for the federal government to manage information, related to the contamination of meat remains a serious concern. The United States Department of Agriculture (USDA) Food Safety and Inspection Service (FSIS) considers reducing human foodborne salmonellosis as one of its top priorities. According to the federal agency, there are an estimated 360,000 cases annually associated with a range of food products. The capacity of federal agencies to set performance standards is a critical observation of a study by the National Advisory Committee on Microbiological Criteria for Foods (2018). Related to government level capacity for meat inspection, Arzoomand et al (2019) acknowledge that subject matter expertise in inspection is critical, along with the importance of good systems in place to manage meat products from carcass to market. Gorton and Stasiewicz (2017) note that in the USA over the past two decades, Class 1 recalls (meaning those which can cause serious threats to health or death) represented 71% of all recalls. The authors link this to large-scale industrial livestock production, and note that the USDA Food Safety and Inspection Service maintain a recall case archive of meat and poultry product recalls since 1994, something of the capacity more likely managed by regional state agencies.

Alternately, Kotsanopoulos. K. and I.S. Arvanitoyannis (2017) examined the variety of food safety and quality standards that form the basis of 3rd party auditing frameworks. The authors recognize

the consumer and public safety over food are fueling a range of public and private responses to recent food scandals, but they also note that this growing plethora of frameworks can be confusing and their effectiveness demands on competency, auditor skills and reference points to broader standards. A related USA-based study examines how Certified Food Manager (CFM) training can help ensure proper food safety practices in decreasing risk factors for foodborne illness. Appling et al (2018) evaluated the results of 546 routine CFM inspections on the USA in 2016 and 2017, and found that 'the effectiveness of food safety management depends on the authority of the person in charge, and the added value of inspectors auditing food safety policies and practices (that are likely established at the state or federal level).

An added dimension to the public-private motivation for food inspection is the growing capacity and opportunity for public access or crowd sourced food safety scoring systems. The increasing frequency of people ordering take-out foods, coupled with the risk of foodborne disease is leading to growing concern with food service establishments. In cities such as Toronto, local public health departments have increasingly publicized food establishments' health inspection scores, while an Ohio, USA-based study found that easy-to-understand, colour-coded system did have an impact on the performance of food establishments (Choi, J., R.L. Scharff, 2017).

2.2 New Technologies: Nanotech, Warning Systems, NIR spectroscopy

Food inspection technologies are numerous and rapidly evolving. An analytical tool that is highly sensitive, specific and reproducible in food inspection are nanozymes, which work at the microscopic scale in detecting quality characteristics. While in early stages of development, there are public concerns over food inspection that are highly specific and reproducible. Nanozymes can be a tool of quality and safety detection even at the agricultural level due to detailed detection. What remains is an in-depth understanding of the principles for food quality, therefore keeping the application currently at the empirical level (Huang, L, et al, 2019). This being said, early warning systems and advances in food inspection technologies are being driven by proactive collaborations between subject matter experts (Allain, V. et al, 2018), often involving the inspection of meat and poultry products.

Related to meat inspection, Barbin et al (2019), looked at near-infrared spectroscopy (NIR) as a potential technique to analyse different cuts of meat. The investigation considered whether NIR is a convenient tool for quality evaluation of deli meats. The tool can detect chemical components in samples, eliminate subjective analysis by food processors alone, and construct real-time data on meat products for documentation, traceability and labelling. The combination of human experts and complimented by new technological tools, could lead to major advances in food inspection effectiveness.

2.3 Small Business Capacity in Food Inspection

Amidst government inspection mandates, frameworks, policies, and protocols, and the ability of 3rd party inspectors to provide additional eyes to the food supply chain, the reality is that in Canada, the majority of food businesses, which are SMEs, need the ability to navigate new advances in food inspection.

With the SFCR, food industry licensees will be required to have at least a Preventative Control system in place and in most cases, to have a written Preventative Control Plan. Some small businesses have clients (such as retail chain stores) that require them to have HACCP or some kind of quality control system in place. HACCP is a major international standard, and while small food business owners are required to follow best practices, those are often voluntary. Torma et al (2019) identify problems with voluntary systems compared to compulsory systems, especially with small food business operations. The study found that several small operators, in this case, from a study in northern Europe, have persistent challenges in complying with several own-check programs and HACCP despite issued instructions and on-site guidance. The authors note that across the EU, and especially for small food businesses, that inspection standards, especially those driven by self-assessment, have greater simplified communication to increase ease of use and understanding.

In a related study from northern Europe (Finland), Kaskela et al (2019) draw attention to the importance of disclosure systems to draw attention to food inspection weaknesses and non-compliance with food safety rules and regulations. The authors note that food business operators (FBOs), can have risk perceptions in disagreement with government standards because several operators work in a business-to-business environmental, where 3rd party certification is required, and may diminish the importance of disclosing results to government officials. The research results, highlight in the EU context, that there are several layers of interaction related to food inspection, from government standards, through to market based, often business-to-business practices which may not be coordinated with broader food safety policies. A robust disclosure system advocated by the authors would increase correction of non-compliance. How might this combination of private sector 3rd party inspection, business-to-business coordination, and alignment work within Canada's new SFCA/SFCR landscape?

2.4 Summary and Key Observations: Section 2 - Top leading themes

Leading Themes	Leading Jurisdictions	Complexity of Use/Transfer to Canada – 1 (being easiest) to 5 (being most complex and difficult)
Data management (government, 3rd parties, SMEs) (Truku, 2018, others)	USA, EU, International	2, dependent on the region of Canada, coordination between federal, provincial and municipal authorities, and food business operators.
Local-regional-federal-intl coordination (training)	USA, EU, International	3, depending on the allocation of resources to training for inspection, and availability of 3rd party inspectors.
New tech (NIR, nanotech) (Huang, 2018)	USA, EU, International	4, dependent on new technological applications in early stages of development, some more specific to sub-sectors, such as meats and seafood, where inspection is often more rigourous.

A leading consideration in recent literature, primarily from leading OECD jurisdictions in North America and the EU, is whether food safety inspection benefits more from government or 3rd party inspectors, or some new combination of the two. In the UK, one study highlighted the importance of 'more eyes' on deck to build the robust, collaboration checks and balances towards a national and regional food safety regime. Several recent studies have looked at inspection in light of changing food consumption trends, of which take-out and ready-to-eat (RTE) meals are growing in popularity. Many studies agree that effective inspection systems need effective managers of food business operations, and the ability to work with inspectors in providing the information required. Crowd-sourcing might also find a growing contribution to inspectors, and restaurant reviews and social media commentaries can raise flags to inspection agencies as to growing risk indicators with certain establishments. Newly emerging technological applications, such as nanotechnology and near infrared (NIR) spectroscopy will allow for faster, and earlier warning systems to detect risk at the microscopic level before problems can spillover into a larger foodborne illness. All these developments also need to keep in mind the landscape of food businesses, and how each is best able to meet new compliance regulations, such as small- and medium- food enterprises in particular.

3. Digitization/Data Science & Predictive Analytics

The digital revolution in marketing, information management, big data, analytics and information capture are having a profound impact on supply chains and the implications for food safety. Online markets, especially during the COVID-19 pandemic are booming, from grocers to distribution logistics centres, and the ability of food businesses and retailers to respond to rapidly evolving consumer needs is critical. What will best practices be in this new reality? Where will responsibility lie in managing data ethically amid innovations in terms of food safety. How can predictive modeling, crowd sourced data, industry standards and shared practice be navigated in Canada, for the CFIA, and within the context of the new SFCR?

3.1 Bayesian Approaches, Deep learning, and NIR modeling

The complexity of data management systems has significantly advanced in the past two decades in particular, where detailed information across supply chains can be tracked with an array of monitors. Knowing which ingredients and products have greater risk of contamination, and using predictive analysis can be modeled using Bayesian statistics. This methodology was recently used in a case study in the Netherlands in the herb and spice supply chain. These ingredients often enter food products from disparate sources, and if allergens may be present in a finished product, detection analysis requires significant processing capacity to determine origin, something which Bayesian statistics are suited to managing. In the case of herbs and spices, they may be potentially contaminated with pathogens like Salmonella, mycotoxins, pesticides and heavy metals, or physical contaminants such as micro pieces of glass. The Dutch study by Bouzembrak et al (2018) sheds light on the potential use of Bayesian modeling to predict hazards in each level of a spice supply chain. Data incorporated into the model also builds on expertise from European Food Safety Agency (EFSA) and World Health Organization (WHO) monitoring system databases. The authors also note that Bayesian models can be compared with random sampling and other risk-based data techniques.

In another related study by Bouzembrak and Martin (2019), emphasis is placed on how food safety risks are driven by factors including climate, economics, human behaviour. Tracking these supply chain factors in their complexity with a holistic approach that can reveal cause-effect relationships and propose mitigation actions is what the authors propose in the use of a Bayesian Network (BN) approach. The research looked at food safety notifications on fruits and vegetables between India, Turkey and the Netherlands over a 10-year period between 2005-2015. Climate and economic factors were also collected. The BN model used machine-learning algorithms and produced optimization for different hazard categories and demonstrated a prediction accuracy of 95% for food safety hazards in fruits and vegetables (Bouzembrak, Y., H.J.M Marvin, 2019). The study demonstrates how expert knowledge and data management systems can combine within a model to assist food safety risk managers to better understand influencing factors.

Two additional studies focused on the Chinese food sector illustrate further the use of Bayesian data modeling. In a study, Bayesian modeling was combined with a meta-analysis to assess food quality and safety to identify food risks in a Chinese market. The authors, Yang et al (2019) claim that Bayesian modeling can be used by public administrators such as the CFIA to assess quality and safety, and by food manufacturers to evaluate their own products. The authors mention the great deal of attention focused on data management approaches that can handle large volumes of information and trade flows. Related to this, a study by Soon, J. M. (2020) used a Bayesian Network model to predict food fraud products originating from China. The types of food fraud were divided into; artificial enhancement, adulteration, documentation, illegal trade, and other unauthorized activities. The Bayesian model predicted the probabilities of fraud in these categories with 85% accuracy, and the author notes the benefit of BN to border controls and inspections for select target food products.

3.1.1 Frontiers in Deep Learning Applications and Next Generation Sequencing

Another large data management methodology gaining attention in food safety management systems is deep learning applications. Zhou, L et al (2019) conducted a literature review of deep learning as a data analysis format to solve food related problems, including quality inspection, and food contamination. The authors considered out deep learning could be used as an advanced data mining tool, and emphasize that 'DL outperforms other methods such as manual feature extractors, conventional machine learning algorithms, and the results indicate that food safety classification and regression problems identified with DL should attract more research efforts in the field of food safety. Zhou et al emphasize that DL in the food system is very early in development, and that to be effective, will require extensive coordination with a range of data sources including imaging, sensory information, and tracking to provide a comprehensive assessment. The study raises the consideration of DL amidst the range of other advances in data management, and applications.

In addition to DL, an advanced data science platform is the use of Next Generation Sequencing (NGS) in applications for food safety and authenticity. NGS platforms are suited for different types of analyses, such as DNA sequencing. NGS is a candidate to become a valuable aid to achieve regulatory compliance and reputation protection particularly for highly complex food matrixes. Hayes et al (2019) claim in their study that NGS is of benefit to consumers for routine analytical checks of authenticity or contamination in the food supply chain. From a CFIA perspective, NGS can be a tool to minimize transaction costs, address non-compliance, and for producers to help with certification check-offs, declare materials and ingredients and differentiate brand integrity. Hayes also adds that 'one criticism on the use of NGS is that it is too data intensive, especially relating to simple, unprocessed foods'. Rather the author notes the value of testing in determining commodity and geographical hotspots. Finally, for NGS to contribute towards food safety testing 'it will be essential that competent testing laboratories become appropriately accredited' (Hayes, E. et al, 2019).

3.2 NIR Spectroscopy, Machine Learning, Data Mining and Multivariate Statistics

3.2.1 NIR Spectroscopy, Machine Learning, Food monitoring

In a study by Richter et al (2019), NIR spectroscopy was used to help identify the origin of vegetables from 6 countries of origin and over 3 years of harvest time were analyzed, and then combined with machine learning tools. When NIR, and machine learning were used with support vector machine classifiers, the country of origin accuracy was 89%. The results demonstrated the potential for NIR (combined with data science applications) as a screening technique for the provenance of vegetables. Given the concern internationally over food fraud of ingredients, and protected origin designations, standards and brand logos, NIR may be the tool to further validate origin.

A range of technologies continue to compete for attention in modern analytical measurement of food integrity, including NIR, mass spectrometry, and chromatography. What Kemsley et al (2019) have drawn attention to is the data management methodology that can handle significant masses of incoming data that can arrives in complex and unwieldy forms. According to the author, there is an assortment of computational methods that are especially suited for dealing with this kind of data, these techniques are multivariate analysis. Kemsley argues that multivariate statistics as the superior method of food safety assessment because the method works with other collection points, and methods such as NIR spectroscopy. Multivariate statistics adds layering to data handling, and this multi-dimensional element is increasingly unavoidable as adulterated foods 'are generally similar in composition to their genuine counterparts' (Kemsley, 2019). In short, the complex challenges facing food safety and authentication require the data management systems that are able to calculate variables and elements beyond the univariate model. This premise is further backed by de Lima et al (2020) where they combined NIR spectroscopy with multivariate analysis to combine physical characteristics detection with a robust statistical analysis. The study demonstrated that NIR combined with multivariate analysis can be a quick and effective method of identifying spice fraud content and avoiding more expensive, time-consuming and complex traditional analysis techniques (de Lima, A et al. 2020).

Related, in a study by Peromingo et al (2020), data mining techniques via decision trees were used to try and predict aflatoxins in cured meats within a HACCP set of protocols. The authors claiming that data mining via decision trees is a reliable and accurate indicator translating into risk mitigation, tracking and proactive response from the food industry.

3.3 Social sentiment data analysis, data collection + quality

It is not just the data on the transport and safety of food products, and their ingredients that need to be managed, but also the social sentiment continually evolving amongst consumers. Overbey, K.N. et al (2017) go beyond data science advances in NIR spectroscopy, Bayesian Network approaches, and multivariate statistics to examine the data behind actual behaviour

change, and the education and training systems required. The authors note that in the USA, each year 48 million people are sickened by different types of foodborne illness, and many are hospitalized and die. The key argument being that foodborne illness cannot be addressed by scientific advancements alone, but by behaviour change, because unsafe practices at the individual level play a crucial role in food safety. Training and education, whether facilitated in greater part in Canada by local agencies, needs to combine traditional and new social media platforms (and the collected data to improve processes). Overbey writes that messaging via content on social media posts to readers can encourage interaction via questions and comments. The study highlights that best practices for social media use are still not fully established, and more controlled studies on impact and benefit in the food safety space are still required.

To further illustrate the importance of data tracking and quality, a study by Gomes-Neves et al (2018), looked at food producers (farmers in particular) in Portugal, seemingly having difficulty providing specific information for food safety compliance. The authors emphasize the need for better forms, systems and training to obtain and integrate the right data from farms to processing. While EU-wide laws can exist, they may not be accurately enforced if submitted data is inaccurate. Gomes-Neves et al write that more effort should be expended (under the EFSA) to train across the food supply chain to provide relevant and valuable information, with the importance to the food chain to protect public health. In the current Canadian context, under the SFCR, the CFIA does not dictate how a company must provide and track their data. While basic templates are provided, there is a caveat that regulated parties may wish to tailor them to suit their business.

3.4 Summary and Key Observations - Section 3 – Top leading themes

Leading Themes	**Leading Jurisdictions**	**Complexity of Use/Transfer to Canada – 1 (being easiest) to 5 (being most complex and difficult)**
Advanced data management systems and analytics (Bayesian model and network approach; deep learning; Next Gen Sequencing; Machine Learning; NIR Spectroscopy	Broad range of application internationally, in cases of advanced analytics, data capacity and infrastructure, and skilled experts are required	4, dependent on the specific type of data management and analytics system. Most relevant to Canada are those data systems beneficial to Canadian trade in our competitive food sub-sectors.
Social sentiment analysis	EU, USA	3, broad spectrum of transfer feasibility to Canada, depending on where most relevant, easier within existing social medial monitoring platforms, and analytics, to greater complexity to make connections between noise and signal in social sentiment regarding food safety

Many of the recent studies on the digital, e-commerce, and analytics frontier of food safety and science seem to be attempting to come to grips with methods, programs, and models to be able to handle the massive amounts of data that the food industry is confronted with. Several recent studies have looked at Bayesian Network approaches, and one theory as to why, is because this method allows for the input of many cause and effect variables into prediction modeling. Rapid developments in predictive analytics, machine and deep learning, and artificial intelligence software, are programs aimed at attempts to make sense of patterns. Data management, when combined with tracking tools, such as NIR spectroscopy, food monitoring indicators, social sentiment analysis, and Internet-of-Things tracking devices can all potentially contribute to prediction tools that optimally would enhance human judgement, whether by government food safety regulators, or private sector food companies.

4. Labelling and Packaging

This section is focused on new developments in labelling and packaging technologies to support greater food safety. Examples of new packages that are more sustainable, minimize plastic waste, meet carbon emission standards, and also provide indicators of food perishability are featured. Researchers are examining the information on packaging labels for consumers regarding safety. Some have exampled what new EU plastic waste directives will imply for food safety standard protocols. The details are contained below.

4.1 Active-Responsive Packaging

4.1.1 Active vs. Responsive Food Packaging – Progress and Technology

The food industry is increasingly facing a broad range of measures directed at reducing packaging waste, primarily in the form of plastics. However, at the same time, the convenience of plastic is undeniable, and furthermore, food safety will need to be ensured with any new sustainability regulations in development.

Yildrim, S. et al (2018) examined the use of the term ‘active packaging in the food industry. The authors pinpoint the consumer drive for safer, healthier, and higher-quality food, with long(er) shelf-life, convenience and transparency. According to the study, ‘active packaging’ is an innovative approach to food product containment. EU regulation defines the term as systems that interact with the food in such a way as to incorporate components that release or absorb substances. Active packaging systems can either ‘absorb’ or ‘emit’, adding compounds or removing them, such as carbon dioxide, oxygen, ethylene or odor. The use of active packaging also goes with the trend towards less adulteration of the food itself through additives and preservatives.

Alternately, in a recent study by Brockgreitens and Abbas (2016), the authors reviewed the different definitions and classes of food packaging technologies, and identify 'responsive food packaging' as emerging in the field, and unlike active packaging, can respond to stimuli in the food or the environment to enable real time food quality and safety monitoring and/or remediation. The authors look at the developments of stimuli responsive materials, and the challenges and future direction to translate research into commercially-viable products. According to the study, responsive packaging will at once be able to reduce spoilage, food waste, recalls and illness outbreaks. From a policy perspective, it is important to consider whether this innovation will be driven by consumers, food brands or regulatory agencies such as the CFIA.

4.1.2 Food packaging – Review and Future Trends

Food packaging needs to face the many demands of a modern consumer marketplace. Oxidation, microbial spoilage, and metabolism are some of the main causes of deterioration in foods during their production, transport, processing, storage, and marketing. These processes directly relate to loss of food quality (including safety), and influence retailer and consumer buying decisions, and public health. Authors Han, J et al (2018), recognized that food packaging needs to continue evolving rapidly to meet the multiple pressures of a demanding consumer public.

A popular and growing category is RTE food items, at grocery stores and in food retail. RTE as well as cook-serve, cook-chill, and cook-freeze food products have grown in popularity. The packaging technologies in which foods are cooked, chilled, refrigerated for storage, and reheated before serving are of prime importance. Packaging material influences cooling rates, and improper handling may also contaminate with foodborne pathogens. In a study by Coorey et al (2018), the authors draw attention to the phenomenal growth of RTE and ready-to-cook food products, and the fact that many of these foods in the recent past have cost governments billions of dollars in illnesses. Emphasis is focused on the cooling rate as a critical control point, in any HACCP-guided plan during product packaging development. Furthermore, foods need to be sealed in proper materials and formats to minimize post-processing contamination. The study concludes with a caution to the limited research on cooling rates related to the risks of foodborne pathogens, and even less on food packaging materials cooling rates, something of consideration for the SFCR/SFCA, and the CFIA.

A 2019 study by Lemos-Junior et al, draws attention to the rise in popularity of Polyethylene Terephthalate (PET) packaging, that replaced glass packaging for soft drinks over a relatively short amount of time. The authors however draw on the growing recognition of the consumer and societal backlash growing against plastic bottle waste, and the pressure for industry to reuse plastic bottles. Shedding light on the use of HACCP principles as a guiding framework, Lemos-Junior et al point out that a HACCP plan within a bottling company can have remarkable improvements in terms of safety and quality of plastic bottle recycling and reuse. Each country (USA, Canada), and region (EU, Asia), will face their own immediate consumer and societal pressures related to packaging, shelf-life, and methods to ensure food safety (Chen, Y. et al, 2020).

A final example of innovation in packaging is modified atmosphere packaging (MAP), a variant of active packaging, commonly used for perishable food products such as seafood in order to inhibit or delay microbial growth and extend shelf life. Kuuliala, L. et al (2018) make the link to the use of data analysis to help in a range of storage and packaging applied to the specific challenge in seafood being shipped. MAP allows for the identification of volatile organic compounds (VOCs) related to spoilage. MAP, combined with multivariate statistics provides analytical methods for the characterization and selection of relevant spoilage indicators.

4.2 Labelling: Consumer Information and Compliance

A study in 2019 by Tinacci, L. et al, examined compliance with current EU labelling regulations, and those products identified as having substitution incidents, in this case, specifically, processed herring in the Italian market. Over 120 samples of herring were examined and their labelling reviewed. The findings of the study were positive, in that substantial labelling compliance and the absence of mislabelling incidents confirmed high levels of food business operators (FBOs) training and control systems to protect and enhance consumers informed choices (Tinacci, L. et al, 2019). The study does come from the context of previous incidents because the nature of seafood products often makes the recognition of species difficult if not impossible to identify in certain cases. In this respect, seafood traceability and proper labelling are key aspects to protect consumers health and food safety. The authors go further in emphasis on the laws and regulations of the EU outlining requirements for the integrity of the seafood supply chain.

Also examining food labelling regulations, in this case, Neill, C.L. and R.B Holcomb (2019) examine the USA-based Food Safety Modernization Act (FSMA), introduced in 2011, that emphasises food safety focused on prevention rather than response to contamination. This is recognized as also in line with the GFSI. The new food safety results created under FSMA give the USDA direct oversight over 80% of the US food supply chain. The authors draw particular attention in the USA to farm produce from smaller farms, often selling directly to farmers markets. The FSMA has a Produce Safety Rule (PSR), which further introduces new on-farm requirements to reduce the risks of pathogenic bacteria, viruses, and parasites in fresh produce. Fruits and vegetables are growing in demand across the USA and Canada, and the need for related and advanced food safety protocols need to match this reality. The underlying value of this study is to demonstrate throughout the supply chain, to farmers, farmers markets, retailers and consumers, the strength of regulatory labelling to increase awareness, education and confidence (Neill, C. L., R.B. Holcomb, 2019).

4.3 Summary and Key Observations - Section 4 – Top Leading Themes

Leading Themes	Leading Jurisdictions	Complexity of Use/Transfer to Canada – 1 (being easiest) to 5 (being most complex and difficult)
Packaging innovation (active packaging, Yildrim, 2018; responsive packaging, Brockgreitens and Abbas, 2016; modified atmosphere packaging, Kuuliala, 2018)	EU, USA, International	3, with a large spectrum of transfer feasibility and demand, depending on the specific packaging innovation. Some already in existence in Canada, other applications, such as modified atmosphere packaging may be led by sub-sectors, and by particular brands for particular products.
Ready-to-eat foods packaging (Coorey, 2018)	EU, USA, Canada, International	3, likely driven by specific regulatory and consumer concerns about RTE food safety. HACCP standards can provide experience for food business operators
Case Studies from USA/EU: Seafood; FSMA, Produce Safety Rule labeling (Neill and Holcomb, 2019)	EU, USA	4, driven largely by case specific relevance to Canadian food businesses and their labeling needs and preferences, such as Canadian seafood or produce, and related risks of fraud.

Food packaging is increasingly coming under scrutiny, not necessarily for food safety reasons alone, as many consumers and food companies internationally are placing pressure on reducing the immense plastic waste that goes with the convenience of easily transportable and light food containers. Leading studies on packaging draw attention to active and responsive packaging as containers can be alert to the changing chemistry of foods, their perishability, and indication as to any spoilage. Along with growing consumer demand for more sustainable, reusable packages, there is an equal trend towards less adulteration, and less use of additives and preservatives, making for an elaborate mix of challenges for the modern food processor. Labelling in turn has an important role in conveying to the food retailer and consumer risk associated with a product. Consumer education about labelling, and its benefit to greater awareness of food safety risks was also reviewed in the current literature.

5. Risk and Preventive Controls Management

In this final section, an extensive scan of both risk assessment and preventive controls management are reviewed.

5.1 Training, Food Safety, Organizational Culture and Change

5.1.1 Training and Education

In the context of food safety, prevention has been a driving mantra, rather than crisis management. International attention has been towards the training, organizational coordination, and culture that goes with best food safety practices. International regulations have also sought to coordinate efforts. In a recent study by Crandall et al (2017), the author draws attention to the Global Food Safety Initiative (GFSI), established by the Consumer Goods Forum in 2000 to increase food safety globally and to attempt to harmonize regulations. In 2013, more than 15,000 GFSI-certified food producers provided input on whether the initiative had lived up to expectations. The findings were surprising. 74% of food manufacturers would go through the GFSI certification process, even if it was not required by retailers because the process reduced the number of 3rd party audits, and improvement manufacturers internal programs. The study was primarily conducted within North America so certain limitations are recognized, but a key take-away from respondents was the cost savings inherent to their experience with the GFSI, especially for small food businesses.

In the USA, another adult education training program focused on behavioural change in food safety was examined by Zan, H. et al (2019). Using a cost-benefit analysis of the Expanded Food and Nutrition Education Program (EFNEP) in Ohio. The study questions the degree of certainty in how people are educated by the program, the length of time the training is effective for, and the level of risk reduction from behaviour change. The authors recognize the value in disease prevention and cost-savings perspective, important to policy makers on fixed budgets, but also note there are data limitations in measuring the critical modeling inputs of; residents affected, educational retention, and intervention effectiveness. The study makes an important contribution to the literature on food safety training, and the variables to consider.

Young et al (2019) further add to the food safety training literature with an examination of food handling interventions in retail and food service. As in the Zan et al study, this study also recognizes the importance of attitudes, knowledge, and behaviour responsiveness in control populations. What is highlighted in the study is that training and educational interventions are only effective if food handler knowledge is followed by improvement in actual behaviour. A case study from Brazil provides a more structured example of how this can be done. According to de Lima (2019), food safety increased in the practices of food trucks in Brazil when trained food experts were on hand to educate food truck owners, and continue to make frequent visits, make

unbiased evaluations, set goals, motivate and state motivated, and train under competent standards and protocols. 'Compliance to hygiene practices increased significantly when food safety consultants participated in the program in Brazil' (de Lima, 2019).

Contributing to the study of food safety culture and staff training, Reynolds and Dolasinski (2019), observe that 'most studies reported knowledge increase post intervention (food safety programs), but few report actual behavioural change. Food service is at the frontline of foodborne illnesses. RTE foods have grown in popularity. The WHO has made the prevention of foodborne illnesses a priority, and food service workers play a major role in prevention. The authors contend that 'increased numbers of food safety training programs and government requirements have yet to significantly lower the number of foodborne illness incidents' (Reynolds, J. M.J. Dolasinski, 2019). The study pinpoints the most common risk factors from; food purchased from unsafe sources, poor personal hygiene, improper cleaning and sanitizing, time-temperature abuse and cross contamination.

A recent study by Barnett, J et al (2020) draws attention to communication between restaurant patrons, food safety concerns, and FBOs opening to training staff receptivity to improvements, allergens and adaptation. '[Food] risk conversations seek to establish trustworthy interactions as the basis on which safety can be maximized…understanding the drivers of, and constraints to, initiating risk conversations as well as the qualities of communication that inspire trustworthiness when eating out has important practical implications for the food industry' (Barnett, J et al, 2020). For some perspective, the US-FDA in 2018 advised US consumers to request allergen information when eating out, but only a few states have laws requiring food establishments to display food allergens or provide training to staff.

Chen et al (2020) compared food safety education and training across three countries in three continents, China, the USA and Peru. The premise of the study was that health professionals are not providing sufficient food safety information to their clients, and the issue in the study centred on lack of patient interested, and 'not enough time for professions to provide the education'. Arguably, health professionals may not be the best candidates responsible for education on food safety? US consumers reported health professionals (physicians, pharmacists, dietitians, and nurses) as the most trustworthy sources of food safety information, especially for the elderly, however less than 40% of dietitians and nurses reporting providing this education to high-risk consumers, including pregnant women and the elderly. 45% of physicians reporting not be confident about general knowledge related to foodborne illnesses. 90% of those surveyed considered their food safety knowledge fair to poor (Scheule, 2004). Food safety risk perception (FSRP), among health professionals, consumers, and food business operators is a continually evolving landscape of both perception, lack of knowledge, and awareness. Nardi et al (2020) developed a guideline and rules to shape a better supply chain understanding to enhance food safety throughout the food industry, including for health experts interacting with individuals for public health.

5.1.2 Organizational Culture and Food Safety Management Systems (FSMS)

FSMS development, certification, and verification frameworks are well-established in food safety regimes, what often remains is how FBOs implement the operation and effectiveness of a FSMS, and train their staff. FSMS have been in existence, according to a study by Manning, L. et al (2019) since the 1950s. The argument of the authors is that these systems are well understood from a validate, and implementation perspective, but the missing piece is in how organizational culture frames operation and efficacy. Manning references HACCP, which is based on Codex Alimentarius Commission, and in turn in the EU, the use of a HACCP-based FSMS requires that 'food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use', and that 'therefore, FSMS must be developed, validated, and then appropriately applied to ensure their efficacy at all steps in the food supply chain from origin in primary production through to the final consumer' (Manning, L. et al, 2019). The recurring reminder by the study, is that while regulatory, and compliance frameworks are quite prevalent, and FBOs in compliance, greater emphasis is shifting towards transformational and cultural maturity in the organization to move from stand-alone technical systems, to the cultural and behavioural framing within side an operation. Manning uses the term 'socio-technical systems' to describe the interaction of FSMS at multiple levels of regulatory, social, technical and behavioural approaches.

De Boeck, E et al (2018) have examined in the Belgian context, understanding the impact of human behaviour on the food safety climate in food companies. The study used an online survey and factor analysis with 136 food companies in Belgium, to determine the amount of training sessions offered to staff per year. The study determines that company leadership, resources, communication and risk awareness provided the degree of food safety culture in an organization. Other factors such as company size, sector, quality control departments, certification, available budgeting had no significant correlation with food safety climate.

De Boeck's food safety report can be considered important for the Canadian context, because as in Belgium, SMEs are common in Canada as well. Over 83% of the over 4400 Belgium food companies are under 20 employees. The study states that 'the implementation of a FSMS is much more challenging to SME food companies. Barriers often mentioned include; lack of resources (time, labour, and finances), and expertise. Food safety needs to take place regularly in organizations, and employees need to perceive it as an issue of importance by their leadership, and as importantly third-party certification may influence FSMS design and implementation but not the associated food safety climate.

Following up to the 2018 study, De Boeck et al, (2020) conducted a study in how the EFSA biohazards panel published a new framework for food safety management adapted to small retail businesses such as grocers, butchers, fishmongers and ice cream parlors, all with the objective of a more hands-on FSMS based on prerequisite programs and hazard analysis of critical control points. The framework is also an initial attempt at harmonization across EU member states. The study looked specifically at butchers in Belgium and the UK, and the proposal of conducing monthly microbiological tests. The proposal was rejected nearly all of those surveyed, stating

that it will burden their jobs (De Boeck, E et al, 2020). The reminder that the food safety policies and programs can largely benefit from human-centred design. To this effect, Jesperson, L et al (2019) propose that a dynamic model of food safety culture develop in stages. These requirements are for; i. organizational effectiveness; ii. organizational culture norms; iii. working groups learning, addressing assumptions, and behaviour; and iv. individual intention and behaviour, all toward a proactive food safety cultural norm in the food organization.

A recent study by Gruenfeldova, J et al (2019) illustrates the gap between EU legislation and actual practice. Food safety knowledge, practice and training was examined among nearly 700 food workers in Ireland. Variables such as job role, years of experience, and level of food safety training acquired were collected. 28% of respondents claimed to never have received training. The authors contextualize the results by adding that fact sheets on food safety published recently by the World Health Organization continue to promote the "Five Keys to Safer Food" as the basis for educational programmes. Training food workers in safe food handling practices, in Ireland, or in Canada, is one of the most critical interventions in the prevention of foodborne illnesses (Gruenfeldova, J et al. 2019).

5.2 Regulatory Change towards Risk Reduction and Preventive Control Guidelines

Evolving government regulations towards risk reduction have increasing placed emphasis towards risk reduction, and preventative controls rather than dealing with crises after the fact. Alvarez-Ordonez, A et al, (2018) examine the importance of management practices, and the training of staff by internal management or external experts to reduce outbreaks of listeriosis in ready-to-eat foods. RTE food producers need to ensure that any food produced is free of bacteria after the cooking process and in line with EU regulations.

In the Canadian context, in a study by Guntzburger et al (2020), nearly 400 food business operators were surveyed about their perceptions of risk in adulterated foods in the Canadian food system as part of the Global Food Safety Initiative (GFSI) scheme. The results were analysed to be a representative sample of producers, processors, and distributors. The study findings were that food processors in particular are the most concerned about the risk of adulteration in ingredients, and this sub-group, the keenest to installing preventative control measures, and the most willing to invest in its prevention.

In the USA context, at a different stage in the food supply chain, small and medium produce growers are now increasingly contended with the preventive controls required in compliance with the Produce Safety Rule of the US Food Safety Modernization Act (FSMA). Critics state the compliance costs are prohibitive. Adjala and Lichtenburg (2018) examine how different farm sizes vary in their expenditures on implementing and reporting on the Produce rule. The authors note that different farming practices (conventional vs. sustainable) spend differently on food safety practices, and also that policy should be modified to the cost burden threshold of compliance by different farm sizes. The study is especially relevant amid the growing consumer demand for

fresh produce, especially from smaller, often farmers market-oriented operations. While Ghostlaw et al (2020) examined the implications of the Produce Safety Rule of the FSMA from the perspective of preventative mitigation via washing systems for produce against e. coli contamination. Tongyu-Wu et al (2020) build on preventative controls in produce hygiene with a study on the cleaning of work environments. The authors add that 'successful FSMS are not measured by time taken for cleaning and sanitizing, as the prolonged time may suggest challenges in practice and infrastructure, but rather taken together, management can foster environments where employees are motivated to identify [proactively] to sustain a food safety program' (Tongyu-Wu, S. et al., 2020).

The passage of the FSMA in 2011 in the USA to regulate growing, harvesting, packing and holding fresh produce is a positive development on preventive controls, now however the gap analysis in this study can address the cost-prohibitiveness of compliance and work towards modification of the policy frameworks.

While Mylona et al (2018) raise the important consideration that all preventative food safety regulations, and their implementation by food business operators will require awareness of both the nutritional and sustainability implications in the costs of compliance (e.g. carbon footprint, packaging design and use of materials), there continue to be no shortage of new policies on food safety monitoring as is evident from the EU microbial residue directive examined by (Alban et al, 2018). What is also an important organizing structure for risk assessment and preventative control management is some time of modeling methodology. Racicot et al (2018) do just that, here in the Canadian context. The authors acknowledge the past decade of work in food safety risk categorization, modeling, decision trees, and priority classification systems to prioritize inspection of those locations at greatest risk to consumers. The study does raise a flag to the lack quantitative risk assessment model that uses a consistent science-based approach to food safety trend analysis

Preventative, proactive systems are being developed by regulators internationally. Zhang (2018) examines the creation of China's National Center for Food Safety Risk Assessment (CFSA), the leading national contributor to food safety standard setting. In China, the National Food Safety Standards (NFSS) framework was established based on the guidance of the Codex Alimentarius to provide clear direction to food safety standard setting on risk analysis principles. The author focuses the study to state that China will need to 'follow a lifecycle approach for food standards, to support the NFSS system to address future challenges with the aim of offering optimal consumer protection and garner trust, domestically and internationally' (Zhang, Z., 2018).

5.3 New Technologies, Tools and Applications

In addition to the recognition of organizational culture, training and education, and regulatory frameworks to foster greater preventative controls towards food safety management, there are a growing array of applied technologies, tools and applications supportive this objective as well.

Seitzinger et al (2019) draw attention to the challenges of conventional data collection of food exposure history and gastrointestinal symptoms associated with foodborne illnesses because of poor compliance with data collection methods. An alternative to this might lie in the use of smartphone technology to collect crowd sourced data on consumption behaviours. *Ethica* is a smartphone-based application that can acquire, store and analyse data on food consumption history through a combination of user-triggered and prompted micro surveys, meal descriptions, and photo diaries. The study authors add 'this enhanced ability to gather in-depth information from sentinel and at-risk target populations could support foodborne illness surveillance' (Seitzinger, P. et al, 2019). Indeed, the spirit of crowd sourcing for collective learning and prevention is also clearly evident in the study by Asselt et al (2018) on a broad range of experts (including food safety, veterinary, and toxicological specialists) in utilizing decision tree methodology. For the tool to be effective, a range of expertise is required, where different stakeholders use the decision tree to have different interpretations of food safety questions and criteria to rank preventative action plans. The study by Asselt et al looked specifically, in the EU context, at the EFSA directive on meat products and chemical contamination risks, prohibited substances, contamination and authorized substances. The authors recommend that food industry operators establish working groups across the supply chain to best utilize decision tree methods. The proliferation of collectively managed, crowd sourced, group planning applications, and methodologies are a positive and proactive development to dealing with the complexity of food safety management systems, whether in the EU or North America.

In a specific case study from the USA, Kwon et al (2020) focus on the restaurant and food service industry, and how it can benefit from better understanding of customer concerns over food allergens. The authors list where food allergy incidents most happen, where employees have been undertrained in informing customers, and the communication between customers, staff, and management. The study also showed that customers take various preventative measures prior to and during dining out to ensure their own safety. In the study, participants were subscribers to AllergyEats.com, a social networking website offering restaurant information for customers with food allergies, so the results may not be generalizable to the overall population, and the results may not reflect attitudes and behaviour of customers outside of the USA.

However, further to contextual food safety research in the USA, Kavanaugh and Quinlan (2020) conducted a recent study on how the food industry use food date labels as information for consumers on the perishability risks associated with RTE and packaged foods. The authors add that consumers might mistake food label dates as information about safety, whereas in many instances the dates are set for quality and freshness. These labels might also contribute to

household food waste. A survey of over 1000 adults in the USA found that only 57% correctly identified what 'best by, use by' meant. The findings indicate that consumer education around the least understood food date label may help to reduce consumer food waste.

Tools to build preventative capacity in the consuming public for food safety is the focus of a study by Clark, J. et al (2020), where the use of a video game was developed to promote handwashing habits in the USA food service industry. In the US, restaurants, catering, and banquet facilities were responsible for 75% of foodborne disease outbreaks between 2009 and 2015. The authors state that future work on tools, such as educational video games, should involving improving the game mechanics or implementing alternative reward mechanisms for promoting handwashing habits in food service (Clark, J. et al, 2020). Indeed, there is a proliferation of measurement tools, group data models, and hardware for food safety decision-making, such as the study from the UK by Gkogka, E. et al (2020) on risk reduction interventions used as the basis for setting risk-based metrics for product groups, to quantitative microbiological risk assessment (QMRA)-style management tools (Christidis et al, 2020), to the use of robotics in the seafood industry in cleaning of fish processing plants that can measurably minimize the potential spread of contamination (Giske, L.A.L et al, 2019).

5.4 Risk Communication

The CFIA and the SFCR can also take on the role of risk communicators with different levels of government across Canada (provincial and municipal), as well as with FBO (food business operators). Here we identify 6 risk communication priorities for consideration:

I. **Food fraud**: Especially amidst the ongoing global pandemic, food trade has continued. With an international trade regime, the CFIA and the SFCR need to remain at once vigilant of the risks associated with potential allergens and associated food contamination risks with imported foods, and be able to communicate this across the country, as well as directly to food distributors, retailers and food service establishments.
II. **Inspection Inconsistency:** As outlined in Section 2 of this report, there continues to evolve a debate over the merits of government and 3rd party inspection of food business establishments. In addition, food businesses themselves may seek certification bodies to conduct their own internal inspections. The CFIA and SFCR can lead in the communication of the risks associated with in consistent food safety inspection, and how to in turn coordinate across local, regional, provincial, national and international standards, regulations and practices.
III. **New Technology Adoption**: As with society at-large, new technological developments are rapidly altering and influencing food production. Applied applications, such as NIR spectroscopy, DNA barcoding, data science and analytics, machine learning, artificial intelligence, social media monitoring, and block chain, are to name a few of the leading examples. The risks, to consumers, food businesses, and governments of data use, data security and integrity are especially heightened, especially as they can relate to food safety.

The CFIA and SFCR can be a clear risk communicator in the use, adoption and management of new technologies

IV. **Zoonotic disease, environmental impact and food safety**: The Covid pandemic is an example of zoonotic disease impacting the globe, as where recent outbreaks of avian and swine flu. Growing consumer and regulatory sentiment towards reducing environmental impact, such as with single-use plastics, or carbon emissions must also be balanced with a strong food safety regime in Canada. The CFIA can contribute to providing leadership and guidance in navigating this complex policy environment.

V. **Risk of ineffective organizational cultural understanding and training**: As demonstrated from Section 5, each food business, depending on its location, theme, mandate, scale, will have variables in its operation that will make its food safety training requirements. The need for a customized, human-centred design program for each food business, is something that the CFIA can help to draw awareness to and facilitate.

5.4 Summary and Key Observations - Section 5 – Top Leading Themes

Leading Themes	Leading Jurisdictions	Complexity of Use/Transfer to Canada - – 1 (being easiest) to 5 (being most complex and difficult)
Global Food Safety Initiative [GFSI] (Crandall, 2017; many authors)	International	3, context dependent for Canadian food businesses trading internationally
Food safety management systems FSMS (esp. food safety training and education for SMEs) (de Boeck, 2018; de Lima, 2019)	UK, EU, International	3, depending on the size of the food business, often with greater training challenges for SMEs
Human-centred design and technology applications such as crowd sourcing (Seitzinger, 2019; Kwon, 2020; many authors)	USA - International	3, depending on the scope of design of training and prevention controls, from simplified continual training and education, to food business tools provided crowd sourced feedback on food products by consumers
USA Case studies: Expanded Food and Nutrition Education Program (Zan, 2019); FSMA in the USA and Produce Safety Rule labeling	USA	3, context specific for Canadian local and provincial authorities in relation to food business capacity, including consumer willingness-to-pay for costs associated with produce safety labelling

There is an extensive literature in recent years that has shifted the focus from responses to crises, to know the proactive, preventive measures required to avoid outbreaks and illnesses in the first place. Many of the studies examined looked at how organizational culture needs to move beyond training and education alone (which are a critical element), but also towards actual behaviour change among food business staff. There is no one-size-fits-all regulation, as different businesses in supply chains have different interactions with international suppliers or with customers and consumers in retail markets. New technologies such as smart phone apps, and crowd sourcing are enabling a new frontier in the possibilities of monitoring, responding to and supporting food safety awareness amongst staff, and interaction with customers.

Conclusion

By way of contextual example, the 2019 US – FDA's 'Food for Thought: Ideas on How to Begin a New Era of Smarter Food Safety' document, highlights how the US initiative is focused on technology enabled traceability and foodborne outbreak response, smarter tools and approaches to prevention, new business models, retail modernization, and a food safety culture. In this light, the SFCR, and the review of leading practices, and scientific research is aligned largely with the initiatives in the USA.

One of the undeniable, and obvious trends that food safety regulators, and food businesses must contend with is the complexity and possibilities of such a vast amount of food products, processes, packaging, and ingredients in the current food supply chain. This has implications for businesses of all sizes, for trade rules, frameworks and certification requirements, and important implications on consumer demand, expectations and associated risks. A natural and creative tension between government regulation, third party certification, and the direct experience of food companies in monitoring and responding to risks associated with food safety continues to exist, in Canada and internationally. The frontiers of technology cannot be understated, whether these are applications in nanotechnology, microbiology, chemistry, tracking devices in the Internet-of-Things or on shipping routes, cold storage monitoring systems, data management systems, machine learning algorithms and predictive analytics, advanced artificial intelligence prediction, can if managed in congruence with human judgement, provide important advances to food safety.

What is also a very evident and recurring trend in the current literature is the movement towards a collective, collaborative, 'all eyes and hands on deck' spirit. No one organization, data methodology, nor regulation, whether in the USA, Canada, or the EU, can track or meet all requirements for food safety. A spirit of flexible, adaptiveness, in organizational cultures, open to letting go of some regulations, enforcing protocols, and safety measures at other times rigorously, and giving access to experts and lay citizens and consumers alike to 'crowd source' inputs remains a remarkable trend.

The SFCR, Canadian Food Safety Strengths and Weaknesses, Gaps, and Recommendations

The SFCR is an innovative regulation designed with the intention of being responsive to emerging threats. This is an especially important strength given the current international predicament of the COVID pandemic, and its implications for food trade, and safety. The SFCR is also strong, to a certain extent, with an emphasis on outcomes-focused approaches. Because of the diversity of food business types across Canada, there is no one-size-fits-all formula. CFIA and SFCR applications, such as the Standard Inspection Procedure are apt to provide inspectors, for example, with the flexibility to adapt to the different situations that arise. The SFCR's requirement for food business to implement a preventive control plan, is also attuned with a proactive strategy that seeks to avoid problems before they occur, which again aligns with

current international developments in food safety. By way of a set of conclusions from this report, the following are the top 5 gaps as priority for consideration, and the associated recommendations that can be considered:

1 a) Gap and Priority: Zoonotic disease

More so than ever, during the current global pandemic, Canada needs to address its response capacity to food safety for international trade as related to zoonotic disease. Zoonoses can pose greater risk in some food sub-sectors, namely in meats, animal products, and seafood.

1 b) Recommendation: Zoonotic disease

The recommendation is for further research into the applicability of data tracking systems (such as DNA barcoding, block chain, QR codes, AI tracking systems), in coordination with our leading trade partners in the USA, the EU, and Asia on the risks and potential spread of zoonotic disease and its impact on food safety.

2 a) Gap and Priority: Inspection for small-and-medium enterprise food businesses

In many of the inspection studies reviewed, there is a combination of government mandated inspection, and emphasis on self-directed inspections for food business operators. Some of the literature highlighted the shortcomings of a good amount of self-directed inspection, especially for SMEs, as experienced in the EU, and recognized as a risk by the SFCR.

2 b) Recommendation: Inspection for small-and-medium enterprise food businesses

While the Preventive Control Plan is a good, proactive initiative, a recommendation is the need for the CFIA to better understand the relationship between food business operators, the different levels of government that those operators need to contend with, and the role of 3rd party inspectors and certifiers. Further research and exploration are required in the Canadian context into the potential of new applications to support inspection for food safety, such as nanozymes and NIR spectroscopy for cost and time saving.

3 a) Gap and Priority: Data management and analytics for food safety

The management of data systems and analytics continues to be one of the most rapidly evolving elements of food trade and food safety. As outlined above, leading companies, in leading jurisdictions, from the USA to the EU, have invested into the frontiers of applications such Bayesian statistics, deep and machine learning, AI, Next Generation Sequencing, and social media monitoring.

3 b) Recommendation: Data management and analytics for food safety

The recommendation is for the CFIA to continually reassess the effectiveness of its data use and tracking mandate under the SFCR to see it is achieving greater food safety, and whether enforcement of data metrics, at least for some indicators, should be considered.

4 a) Gap and Priority: Food safety packaging innovation

Innovation in packaging is one of the fastest evolving sub-sectors of the food industry, from adaptive, to active, responsive and modified atmosphere. With the growing fact as a result of the pandemic, more Canadians are buying ready-to-eat foods, and packaged, prepared foods.

4 b) Recommendation: Food safety packaging innovation

The recommendation is for the CFIA, and affiliated regulators, to examine the challenges to maintain food safety, while also address the regulatory and consumer sentiment towards reducing single-use plastics, and the associated environmental strains of greater plastic and packaging waste on ecosystems.

5 a) Gap and Priority: Food safety organizational culture, training and continual improvement

One of the strongest themes throughout the literature reviewed is the importance (and challenge) of food safety training, education, and continual improvement at the level of organizational culture (most often in small food businesses). Food safety management systems, directed by food business operators, and their staff, have a tall order. There often needs to be awareness of and compliance with local, regional, national and at times international standards of practice.

5 b) Recommendation: Food safety organizational culture, training and continual improvement

A recommendation is for the CFIA, and the SFCR to further research the principles of human-centred design in food safety training, for food business operators to understand the motivation, and communication that will lead to lasting change and awareness for staff. With this recommendation is to further research the utilization of new technology applications that can facilitate better learning and retention of food safety practices, while reducing the time and costs associated with its education.

References

Abrokwah, S. et al. 2020. Microbial assessment of plastic bottles reused for packaging food products in Ghana. *Food Control*. 109:106956.

Adalja, A., E. Lichtenburg. 2018. Produce growers' cost of complying with the Food Safety Modernization Act. *Food Policy*. 74: 23-38.

Alban, L. et al. 2018. Modernizing the antimicrobial residue monitoring programs for pig meat in Europe – The balance between flexibility and harmonization. *Food Control*. 86: 403-414.

Allain, V. et al. 2018. Designing an innovative warning system to support risk-based meat inspection in poultry slaughterhouses. *Food Control*. 89: 177-186.

Alvarez-Ordonez, A. et al. 2018. Production of safer food by understanding risk factors for *L. monocytogenes* occurrence and persistence in food processing environments. *Journal of Food Safety*. 38: 1-7.

Appling, X. S., et al. 2018. Understanding the Relation between Establishment Food Safety Management and Risk Factor Violations Cited during Routine Inspections, *Journal of Food Protection*, 81(12): 1936-1940.

Arzoomand, N. et al. 2019. Flexible distribution of tasks in meat inspection – A pilot study. *Food Control*. 102: 166-172.

Badia-Melis, R. et al. 2018. New trends in cold chain monitoring applications – a review, *Food Control*, 86: 170-182.

Barbin, D.F. et al. 2020. Identification of turkey meat and processed products using near infrared spectroscopy. *Food Control*. 107: 106816.

Barnett, J. et al. 2020. Conversations about food allergy risk with restaurant staff when eating out: A customer perspective, *Food Control*, 108: 1-9.

Bouzembrak, Y., H.J.P. Marvin. 2019. Impacts of drivers of change, including climatic factors, on the occurrence of chemical food safety hazards in fruits and vegetables: A Bayesian Network approach. *Food Control*. 97: 67-76.

Bouzembrak, Y. et al. 2018. Effective sampling strategy to detect food and feed contamination: Herbs and spices case. *Food Control*. 83: 28-37.

Bouzembrak, Y. et al. 2018. Application of Bayesian Networks in the development of herbs and spices sampling monitoring system. *Food Control*. 2018. 83: 38-44.
Brockgreitens, J., A. Abbas. 2016. Responsive Food Packaging: Recent Progress and Technological Prospects, *Comprehensive Reviews in Food Science and Food Safety*. Vol 15: 3-15.

Cadieux, B. et al. 2019. Gap analysis of the Canadian food fraud regulatory oversight and recommendations for improvement. *Food Control*, 102: 46-55.

Charlebois, S. & C. Le Vallee. 2014. Food Safety Performance, *Conference Board of Canada.*

Chen, Y. et al. 2020. Effects of different salt concentrations and vacuum packaging on the shelf-stability of Russian sturgeon (*Acipenser gueldenstaedt*) stored at 4C. *Food Control*. 109: 106865

Chen. R. et al 2018. The causal impact of HACCP on seafood imports in the US: An application of difference-in-differences within the gravity model, *Food Policy*, 79, 166-178.

Chen, H. et al. 2020. Food safety education attitude and practice among health professionals in China, Peru, and the USA. *Food Control*. 109: 106945.

Christidis, T. et al. 2020. A comparative exposure assessment of foodborne, animal contact and waterborne transmission routes of Salmonella in Canada, *Food Control*. 109: 106899

Choi, J., R. L. Scharff. 2017. Effect of a Publicly Accessible Disclosure System on Food Safety Inspection Scores in Retail and Food Service Establishments, *Journal of Food Protection*. 80(7): 1188-1192.

Clark, J. et al. 2020. Perceptions of a video game to promote handwashing habits in foodservice, *Food Control*, 107: 1-6.

Coorey, R. et al. 2018. The Impact of Cooling Rate on the Safety of Food Products as Affected by Food Containers. *Comprehensive Reviews in Food Science and Food Safety*. Vol. 17: 827-840.

Crandall, P.G. et al. 2017. Impact of the Global Food Safety Initiative on Food Safety Worldwide: Statistical Analysis of a Survey of International Food Processors, *Journal of Food Protection*. Vol 80 (10): 1613-1622.

Creydt, M., M. Fischer. 2019. Blockchain and more – Algorithm driven food traceability. *Food Control*, 105: 45-51.

De Boeck, E. et al. 2020. Evaluation of a simplified approach in food safety management systems in the retail sector: A case study of butcheries in Flanders, Belgium and Lancashire, UK. *Food Control*, 108: 1-9.

De Boeck, E. et al. 2018. Quantitative study of food safety climate in Belgian food processing companies in view of their organizational characteristics. *Food Control*. 88: 15-27.
De Lima, A. et al. 2020. Fast quantitative detection of black pepper and cumin adulterations by near-infrared spectroscopy and multivariate modeling, *Food Control*, 107:106802.

De Lima, D., et al, 2019. Implementation of good hygiene practices in food trucks with and without the intervention of a food safety expert, *Journal of Food Safety*, 1-7, 39.

Dzwolak, W. 2016. Practical Aspects of Traceability in Small Food Businesses with Implemented Food Safety Management Systems (FSMS), *Journal of Food Safety*, 36: 203-213.

Eygue, M. et al. 2020. Development of a risk-ranking framework to evaluate simultaneously biological and chemical hazards related to food safety: Application to emerging dietary practices in France, *Food Control* 115 (2020) 107279.

Fleetwood, J. et al. 2019. As clean as they look? Food hygiene inspection scores, microbiological contamination, and foodborne illness, *Food Control*. 96: 76-86

Giske, L.A.L, et al. 2019. Experimental study of effectiveness of robotic cleaning for fish-processing plants. *Food Control*. 100: 269-277.

Government of Canada [GoC], 2018. Understanding the Safe Food for Canadians Regulations: A Handbook for Food Businesses, *Canadian Food Inspection Agency*, 2018.

Ghostlaw, T. et al. 2020. Impact of various postharvest wash water conditions on the performance of peracetic acid against Escherichia coli 0157:H7 over time, *Food Control*, 109: 106891.

Gkogka, E. et al. 2020. Risk assessment of Clostridium perfringens in Cornish pasties in the UK, *Food Control*. 108: 1-14.

Gruenfeldova, J. et al. 2019. A study of food safety knowledge, practice and training among food handlers in Ireland. *Food Control*. 105: 131-140.

Gomes-Neves, E. et al. 2018. Food Chain Information: Data Quality and Usefulness in Meat Inspection in Portugal. *Journal of Food Protection*. 81 (11): 1890-1896.

Gorton, A., M. Stasiewicz. 2017. Twenty-Two Years of U.S. Meat and Poultry Product Recalls: Implications for Food Safety and Food Waste, *Journal of Food Protection*, 80(4), 674-684.

Guntzburger, Y. et al. 2020. Food industry perceptions and actions towards food fraud: Insights from a pan-Canadian study, *Food Control*, 113 (2020) 107182.

Han, J. et al. 2018. Food Packaging: A Comprehensive Review and Future Trends. *Comprehensive Reviews in Food Science and Food Safety*. Vol 17: 860-877.
Hayes, E. et al. 2019. The future of NGS (Next Generation Sequencing) analysis in testing food authenticity. *Food Control*. 101: 134-143.

Huang, L. et al. 2019. Development of Nanozymes for Food Quality and Safety Detection: Principles and Recent Applications. *Comprehensive Reviews in Food Science and Food Safety*. Vol. 18: 1496-1513.

Jansen, W. et al. 2019. Brucella-positive raw milk cheese sold on the inner European market: A public health threat due to illegal import? *Food Control*, 100: 130-137.

Jespersen, L et al. 2019. The impact of maturing food safety culture and a pathway to economic gain. *Food Control*. 98: 367-379.

Kaskela, J. et al. 2019. Food business operators' opinions on disclosed food safety inspections and occurrence of disagreements with inspector grading. *Food Control*. 105: 248-255.

Kavanaugh, M., J. L. Quinlan. 2020. Consumer knowledge and behaviours regarding food date labels and food waste. *Food Control* 115 (2020) 107285

Kemsley, E. K., et al. 2019. Multivariate statistics: Considerations and confidences in food authenticity problems, *Food Control*. 105: 102-112.

Kotsanopoulos. K., I. S. Arvanitoyannis. 2017. The Role of Auditing, Food Safety, and Food Quality Standards in the Food Industry: A Review. *Comprehensive Reviews in Food Science and Food Safety*. Vo 16: 760-775.

Kuuliala, L. et al. 2018. Multivariate statistical analysis for the identification of potential seafood spoilage indicators. *Food Control*, 84: 49-60.

Kwon, J. et al. 2020. Knowledge, attitudes, and behaviours about dining out with food allergies: A cross-sectional survey of restaurant customers in the United States. *Food Control*. 107: 1-11.

Lemos Junior, W.J.F. et al. 2019. Reuse of refillable PET packaging: Approaches to safety and quality in soft drink processing, *Food Control*. 100: 329-334.

Limoges, M., C. Donnelly. 2019. FDA's Cheese and Cheese Products Compliance Program guideline criteria for non-toxigenic *Escherichia coli*: A retrospective analysis of impacts on domestic and imported cheeses, *Food Control*. 106: 1-9.

Macready, A. L. et al. 2020. Consumer trust in the food value chain and its impact on consumer confidence: A model for assessing consumer trust and evidence from a 5-country study in Europe. *Food Policy* 92 (2020) 101880.

Manning, L. 2020. Moving from a compliance-based to an integrity-based organizational climate in the food supply chain. *Comprehensive Reviews in Food Science and Food Safety*, 2020: 19:995-1017

Manning, L. et al, 2019. The Evolution and Cultural Framing of Food Safety Management Systems – Where From and Where Next?, *Comprehensive Reviews in Food Science and Food Safety*. 18: 1770-1792.

Mylona, K. et al. 2018. Viewpoint: Future of food safety and nutrition – Seeking win-wins, coping with trade-offs. *Food Policy*. 74: 143-146.

Nardi, V. A. M. et al. 2020. A meta-analytic review of food safety risk perception. *Food Control*, 112 (2020) 107089.

National Advisory Committee on Microbiological Criteria for Foods. 2019. Response to Questions Posed by the Food Safety and Inspection Service Regarding *Salmonella* Control Strategies in Poultry. *Journal of Food Protection*. 2019. 82(4): 645-668.

Neill, C. L., R. B. Holcomb. 2019. Does a food safety label matter? Consumer heterogeneity and fresh produce risk perceptions under the Food Safety Modernization Act. *Food Policy*. 85: 7-14.

Overbey, K.N. et al. 2017. A Systematic Review of the Use of Social Media for Food Safety Risk Communication, *Journal of Food Protection*. Vol 80 (9): 1537-1549.

Park, J. M. 2020. Introduction of highly effective proactive food safety management programs into food distribution channels: For safe food labelling and safe advertisements, *Journal of Food Safety*. 40 (2020): 12751

Peromingo, B. et al. 2020. Application of data mining techniques to predict the production of aflatoxin B1 in dry-cured ham. *Food Control*, 108: 106884.

Racicot, M. et al. 2018. Quantifying the impact of food safety criteria in the Canadian Food Inspection Agency risk assessment model for food establishments through Expert Elicitation. *Food Control*. 92: 450-463.

Reynolds, J., M.J. Dolasinski. 2019. Systematic review of industry food safety training topics & modalities. *Food Control*. 105: 1-7.

Richter, B. et al. 2019. Food monitoring: Screening of the geographical origin of white asparagus using FT-NIR and machine learning, *Food Control*. 104: 318-325.

Seitzinger, P. et al. 2019. Compliance Rates, Advantages, and Drawbacks of a Smartphone-Based Method of Collecting Food History and Foodborne Illness Data. *Journal of Food Protection*, 82(6): 1061-1070.

Shang, X., G. T. Tonsor, 2019. Food safety recall effects across meat products and regions. *Food Policy*. 69: 145-153.

Shehata, H. R. et al. 2018. DNA barcoding as a regulatory tool for seafood authentication in Canada. *Food Control*. 92: 147-153.

Soon, J. M., 2020. Application of Bayesian Network Modelling to Predict Food Fraud Products from China. *Food Control* 114 (2020) – 107232.

Souza-Martins, W. et al. 2018. Adaptation and Validity Assessment of the Food Safety Climate Self-assessment tool. *Journal of Food Safety*. 38: 1-10.

Spence, M. et al. 2018. Exploring consumer purchase intentions towards traceable minced beef and beef steak using the theory of planned behaviour. *Food Control*, 91: 138-147.

Tinacci, L. et al. 2019. Labelling compliance and species identification of herring products sold at large scale retail level within the Italian market. *Food Control*. 106: 106707

Tomasevic, I. et al. 2020. Comprehensive insight into the food safety climate in Central and Eastern Europe. *Food Control* 114 (2020) – 107238.

Tongyu-Wu, S. et al. 2020. Infrastructure, sanitation, and management practices impact Listeria monocytogenes prevalence in retail grocery produce environments, *Food Control*, 109: 106911.

Torma, K. et al. 2019. Compliance in own-check systems poses challenges in small-scale slaughterhouses. *Food Control*. 95: 27-33.

Turku, M. et al. 2018. Differences between official inspections and third-party audits of food establishments. *Food Control*. 85: 459-465.

van Asselt. E.D. et al. 2018. Risk-based monitoring of chemical substances in food: Prioritization by decision trees. *Food Control*. 93: 112-120.

van Asselt, E.D. et al. 2017. Overview of Food Safety Hazards in the European Dairy Supply Chain, *Comprehensive Reviews in Food Science and Food Safety*. Vol 16, 59-75.

Xu, J. et al. 2019. Glyphosate contamination in grains and foods: An overview, *Food Control*, 106: 1-8.

Yang, Y. et al. 2019. Application of Bayesian modelling to assess food quality & safety status and identify risky food in China market. *Food Control*. 100: 111-116.

Yildirim, S. et al. 2018. Active Packaging Applications for Food, *Comprehensive Reviews in Food Science and Food Safety*, Vol 17: 165-199.
Young, I. et al. 2020. Observational assessment of food safety behaviours at farmers' markets in Ontario, Canada: A cross-sectional study. *Food Control*. 108: 1-8.

Young, I. et al. 2019. Effectiveness of Food Handler Training and Education Interventions: A Systematic Review and Meta-Analysis, *Journal of Food Protection*. 82 (10): 1714-1728.

Zan. H. et al. 2017. An Economic Evaluation of Food Safety Education Interventions: Estimates and Critical Data Gaps, *Journal of Food Protection*, 80(8): 1355-1363

Zhang, Zhe. 2018. Transformation of China's food safety standard setting system – Review of 50 years of change, opportunities and challenges ahead. *Food Control*. 93: 106-111.

Zhou, L. et al. 2019. Application of Deep Learning in Food: A Review. *Comprehensive Reviews in Food Science and Food Safety*, Vol 18: 1793-1811.