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The Canadian food cold chain: A legislative, scientific, and prospective overview

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ABSTRACT

The aim of this work is to review the state and performance of the food cold chain in Canada, highlight current and potential research on the cold chain, and identify areas for improvement. The cold chain in Canada faces unique challenges related to the succession of warm (summer) and freezing (winter) conditions during the year, the long transportation distances, and the presence of hundreds of northern communities not accessible year-round by road, rail or sea. Time-temperature profiles indicate that the temperature of perishable foods is successfully kept in the desired range along a typical Canadian four-step cold chain in winter but that improvements should be made to lower the temperature during transportation and storage at the processor in summer. The recent development of the Canadian GIS-based Risk Assessment, Simulation, and Planning (CanGRASP) tool represents a significant achievement that will make it possible to simulate the performance of the cold chain at a national scale and opens promising avenues for preventing foodborne outbreaks and investigating new food management systems designed to reduce food waste and energy consumption. Making community-specific adjustments to cold chains that deliver food to northern communities should be a major priority for future cold chain improvements, as it could help alleviate their higher-than-average concerns about food security.

Chaîne du froid alimentaire au Canada: Aperçu législatif, scientifique et prospectif

Mots-clés: Chaîne du froid; Chaîne d'approvisionnement; Denrées périssables; Sécurité alimentaire; Transport alimentaire; Populations du nord

1. Introduction

Temperature is the main factor affecting the safety and quality of perishable foods (Hertog et al., 2014). To avoid shrinkage and the growth of foodborne pathogens, most fruits, vegetables, seafood products, meat, and dairy products need to be kept chilled or frozen throughout all steps from production to consumption. The temperature of chilled or frozen foods is controlled throughout most supply chains using refrigeration systems. The series of refrigeration operations used to keep foods at the required temperature is referred to as the cold chain.

The critical role of the cold chain with respect to food waste is well established. The cold chain can cause food waste if it involves inappropriate food management, which creates local oversupplies or prolongs storage periods, or inappropriate storage conditions, which decrease food shelf life (Young, 2012; Jedermann et al., 2014; Gwanpua et al., 2015). In Canada, it is estimated that nearly half (40%) of the food produced is wasted (Young, 2012). Food waste has a significant economic impact: the food wasted annually in Canada is worth more than $25 billion, nearly 2% of Canada's gross domestic product (Young, 2012). Additional consequences of food waste include the loss of the energy consumed for food processing and storage, the production of methane and other greenhouse gases during food degradation, and the societal impact of wasting food in a world where the population is constantly growing and land resources are reaching the saturation point (Young, 2012; Jedermann et al., 2014; Gwanpua et al., 2015).

The cold chain also has a significant environmental impact due to its high energy consumption and the leakage of refrigerants into the atmosphere (Gwanpua et al., 2015). Refrigeration is an energy-intensive process that accounts for 15% of worldwide electricity production (Coulomb, 2008). Leakage of refrigerants is responsi-

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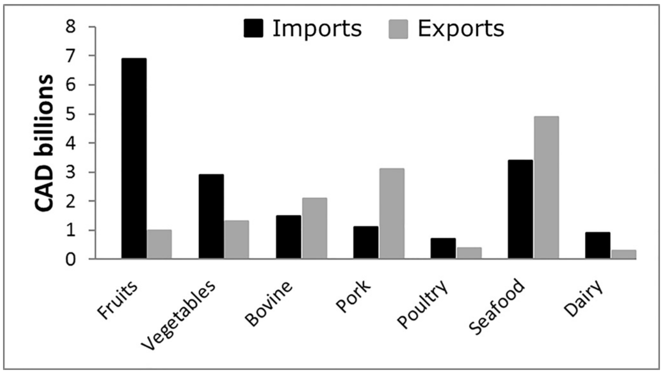

Fig. 1. Value, in Canadian dollars, of chilled or frozen foods imported to and exported from Canada in 2014 (data taken from: Agriculture and Agri-Food Canada, 2015a,b,c,d,e; Canadian Dairy Information Centre, 2015).

ble for approximately 15% to 20% of the global warming effect of refrigeration (Garnett, 2007; Coulomb, 2008; James and James, 2010). In addition, significant greenhouse gas emissions are caused by fuel consumption by mobile refrigeration units, and air transport is the most energy-intensive method of transporting food: it is estimated that the same amount of fuel can transport 5 kg of food 3800 km by ship, 2400 km by rail, or 740 km by truck, but only 43 km by air (Brodt et al., 2007). In the United Kingdom, it is estimated that food refrigeration is responsible for 2% to 4% of the country's total greenhouse gas emissions (Garnett, 2007). Food refrigeration and the cold chain are also believed to contribute significantly to Canada's greenhouse gas emissions, especially considering the significant distances to market and the reliance on air transport to supply northern communities (Nutrition North Canada, 2015).

The cold chain varies significantly from region to region around the world. Cold chains need to be adjusted in response to several factors, including legislation, market trends, imported and exported products, climate, transport distances, available technologies, and sources of energy. The purpose of this article is to review the state of the food cold chain in Canada. First, an overview of the food industry, focusing on chilled and frozen foods, is presented. Next, relevant legislation is introduced, followed by a description of the characteristics and challenges inherent to the Canadian food cold chain. Last comes a discussion of current and prospective research projects on the application of GIS-based approaches for simulating and improving the cold chain in terms of food safety and quality and energy efficiency.

2. Trade balance for chilled or frozen foods

Cold chains can be significantly different for imported and exported foods. For imported foods, the destination of the cold chain is generally consumption-related, and the end points of many cold chains are dense consumer markets. By contrast, the cold chain for exported foods starts with production or processing, which means that the starting points of many cold chains are sparsely distributed across farms or processing plants. The cold chain for exported foods may also encompass a smaller range of food products, as it is limited to food produced or processed locally (Rodrigue, 2014).

Relevant resources on food imports and exports can be found in the industry reports published yearly by Agriculture and Agri-Food Canada and the monthly updates of the Canadian International Merchandise Trade Database maintained by Statistics Canada. Canada is a major exporter of fresh, chilled and frozen meat, especially bovine products and pork, as well as seafood products (Fig. 1). However, Canada imports most of its fruits and vegetables because local production is relatively limited given the country's cold climate. The state (chilled or frozen) of imports and exports is specific to the food product. The majority of bovine products and salmon products that are imported and exported are fresh or chilled, while the majority of pork imports, crab exports and lobster exports are frozen (Fig. 2). The trade balance of perishable food shows significant yearly variations. As an example, Fig. 3 shows the trade balance for beef and veal from 2010 to 2016. The trade balance became negative in 2011 and 2012, owing to the strength of the Canadian dollar relative to the American dollar, the exportation of low-value meat cuts, and the decline in the size of the Canadian beef herd (Chan, 2012). Exports nearly doubled from 2012 to 2016, leading to a significant improvement in the trade balance. From 2015 to 2016, imports decreased by $0.3 billion and the trade balance reached $0.9 billion, the highest level since 2006 (Agriculture and Agri-Food Canada, 2017). The United States is Canada's largest trading partner by a wide margin, owing to its geographic proximity and dense population, and the trade agreements between the two countries. Approximately 50% of Canada's food trade (imports and exports) takes place with the United States. Other major trading partners include China, Japan and Mexico (Prentice and McLachlin, 2008; Farm Credit Canada, 2014).

3. Food safety legislation

The food safety controls in place in Canada are mainly at the federal level. The industry must comply with the requirements and good manufacturing practices established under the *Food and Drugs Act, Safe Food for Canadians Act, Meat Inspection Act, Canadian Agricultural Products Act*, and *Fish Inspection Act*, as well as their regulations. To that end, the industry has three main public partners. Health Canada establishes food safety requirements, policies and guidelines in accordance with the relevant acts and regulations. The Canadian Food Inspection Agency is responsible for enforcement and has developed the Canadian Food Safety and Quality Program, which outlines the requirements for effective food safety management systems (Canadian Food Inspection Agency, 2014). Agriculture and Agri-Food Canada provides technical and scientific support to the food industry. Additional legislation, codes or guidelines are also in place at the provincial level for food processing plants outside federal jurisdiction or in addition to the federal legislation (Jol et al., 2007; Quigley, 2014). It is important to note that regulations on the safety and quality of perishable food are constantly being reviewed to take into account changes in technologies, good practices and international standards (Jol et al., 2006). As an example, public consultations were carried out in early 2017 in Canada regarding the proposed Safe Food for Canadians Regulations (Canadian Food Inspection Agency, 2017). These new regulations are anticipated in 2018 and would replace the regulations made under the *Meat Inspection Act*, the *Canadian Agricultural Products Act*, and the *Fish Inspection Act*, with the objective of modernizing current regulatory frameworks and providing regulations with consistent requirements for all food products that are internationally recognized (Canadian Food Inspection Agency, 2017).

The critical role of the cold chain in the preservation of food safety and quality is recognized by regulatory institutions in Canada (Jol et al., 2007). The Canadian Food Safety and Quality Program encourages stakeholders in the cold chain, including those involved in food transportation and storage, to adopt a hazard analysis critical control point (HACCP)-based approach to food safety (Canadian Food Inspection Agency, 2014). Generic HACCP models have been developed for manufacturers of meat, poultry, processed eggs, and ready-to-eat lettuce and for storage facilities in order to facilitate the development of a HACCP system (Canadian Food Inspection Agency, 2015). For federally inspected meat and poultry processing plants, HACCP is mandatory (Jol et al., 2007). The HACCP-based approach to food safety adopted in Canada, complemented by a food inspection system strengthened by the re-

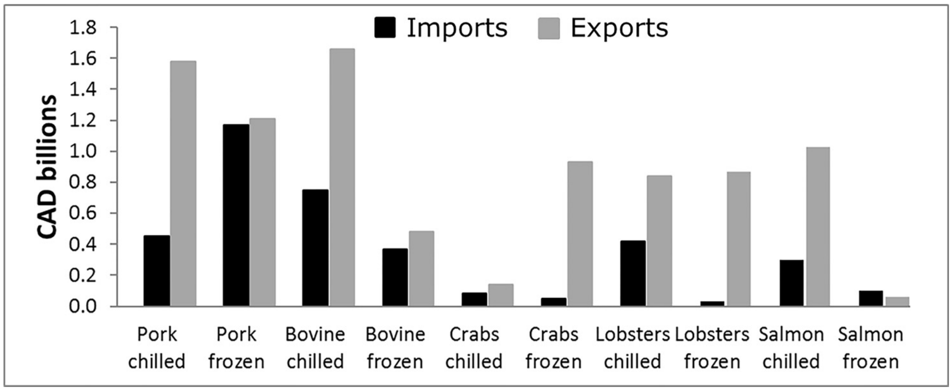

Fig. 2. Value, in Canadian dollars, of various perishable food products imported and exported from Canada according to their state (chilled or frozen) in 2016 (data taken from Statistics Canada, 2017).

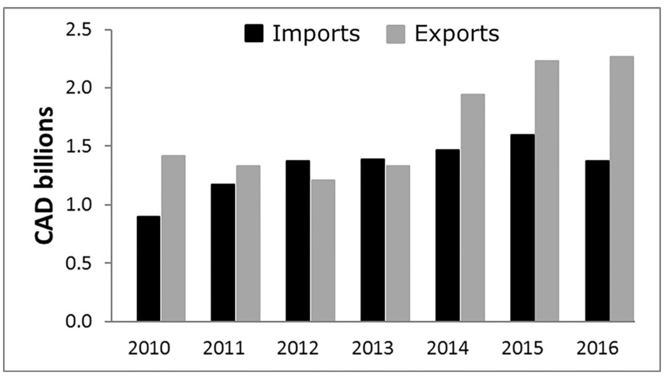

Fig. 3. Yearly variation of the value, in Canadian dollars, of bovine products (beef and veal) imported and exported from Canada (data taken from Agriculture and Agri-Food Canada, 2017).

cently adopted *Safe Food for Canadians Act*, is a flexible approach for implementing food safety controls systems suitable for the special characteristics of each stakeholder in the cold chain and places the food industry at the forefront of Canada's strategy for food safety (Martinez et al., 2007).

Canadian legislation and regulations do not specify a temperature requirement that is enforced across a large range of perishable food products or stages of the cold chain, as the Canadian food safety and quality assurance system is largely based on a flexible framework with shared responsibility between producers, processors, transporters, distributors, retailers and consumers. However, explicit temperature requirements do exist for some perishable food product categories. The *Meat Inspection Regulations* specify that establishments where meat is refrigerated, processed, stored and labeled are required to have adequate means to monitor temperature. Refrigeration is defined in the regulations as maintaining the temperature of meat below 4 °C, but above freezing conditions (Meat Inspection Regulations, 1990). The *Fish Inspection Regulations* state that refrigeration facilities shall freeze 25mm-thick block of unpackaged fillets to −18 °C in 2 hours or less. During storage, the temperature of fish products should be checked at least once every day, and the temperature records kept for a period of at least 3 years. With regard to transportation, the *Fish Inspection Regulations* also specify that fish products should be refrigerated such that their temperature increases by less than 5.5 °C from their loading temperature (Fish Inspection Regulations, 2017). The refrigeration and freezing temperatures specified in the Canadian regulations on meat and fish products are in accordance with those set out in U.S. and European legislation. For instance, the 2013 U.S. Food Code, administered by the U.S. Food and Drug Administration, specifies that perishable chilled food should be maintained at a temperature of 5 °C or lower, while frozen food should be stored at a sufficiently low temperature to keep the food frozen (U.S. Public Health Service, 2013).

4. Characteristics of the Canadian food cold chain

4.1. Canadian retail food distribution chain

In Canada, processed foods sold at retail generally move through a four-step supply chain consisting of growers/suppliers, processors, distribution centers, and retail stores, as illustrated in Fig. 4. According to LeBlanc et al. (2015), the top five Canadian food retailers accounted for about 79% of food sales in Canada. Approximately 82.2% of the Canadian population lives within 5-km (urban areas) or 20-min drive (rural areas) of a retail outlet of the top five Canadian food retailers (Fig. 5). The two biggest Canadian retailers have retail outlets in each of the 10 Canadian provinces (Hashemi Beni et al., 2011). There are approximately 3000 retail outlets in Canada, two-thirds of which are located in the provinces of Ontario and Quebec. The relationship between producers and processors is many-to-many. The processors and distribution centers also have a many-to-many relationship. Lastly, there is a many-to-one relationship between distribution centers and retail outlets, meaning that each retail outlet is supplied by a single distribution center for each category of food (e.g. produce, dairy, meat). Communities in northern Canada that are not accessible by road have been supplied with food by air under the Nutrition North Canada Program since April 2011. This program replaced the former Food Mail Program (Indian and Northern Affairs Canada, 2009). Selected food products are delivered by road to one of the 20 entry points shown in Fig. 5 and then transported to their final destination by air.

4.2. Time-temperature along the cold chain

In Canada, the ambient temperature varies significantly by time of year and location, with daily average lows and highs ranging from approximately −30 °C to 30 °C (Statistics Canada, 2007). Refrigeration systems are required to preserve the safety and quality of perishable foods in summer, while heating systems are used in winter to prevent freezing injury to chilled foods.

Time-temperature profiles of ready-to-eat lettuce along a five-step cold chain (processor storage, transportation to the distribution center, distribution center storage, transportation to retail, and retail storage) in Canada were measured by McKellar et al. (2012, 2014). The temperature was monitored for four shipments of ready-to-eat lettuce in summer (July-August) and in winter (January-February). A total of nine clamshells, placed at different positions within stacked pallets, were instrumented for each shipment. In winter, the desired range of temperatures was successfully maintained throughout the cold chain. The highest average temperature, 4.1 °C, was observed during retail storage, but

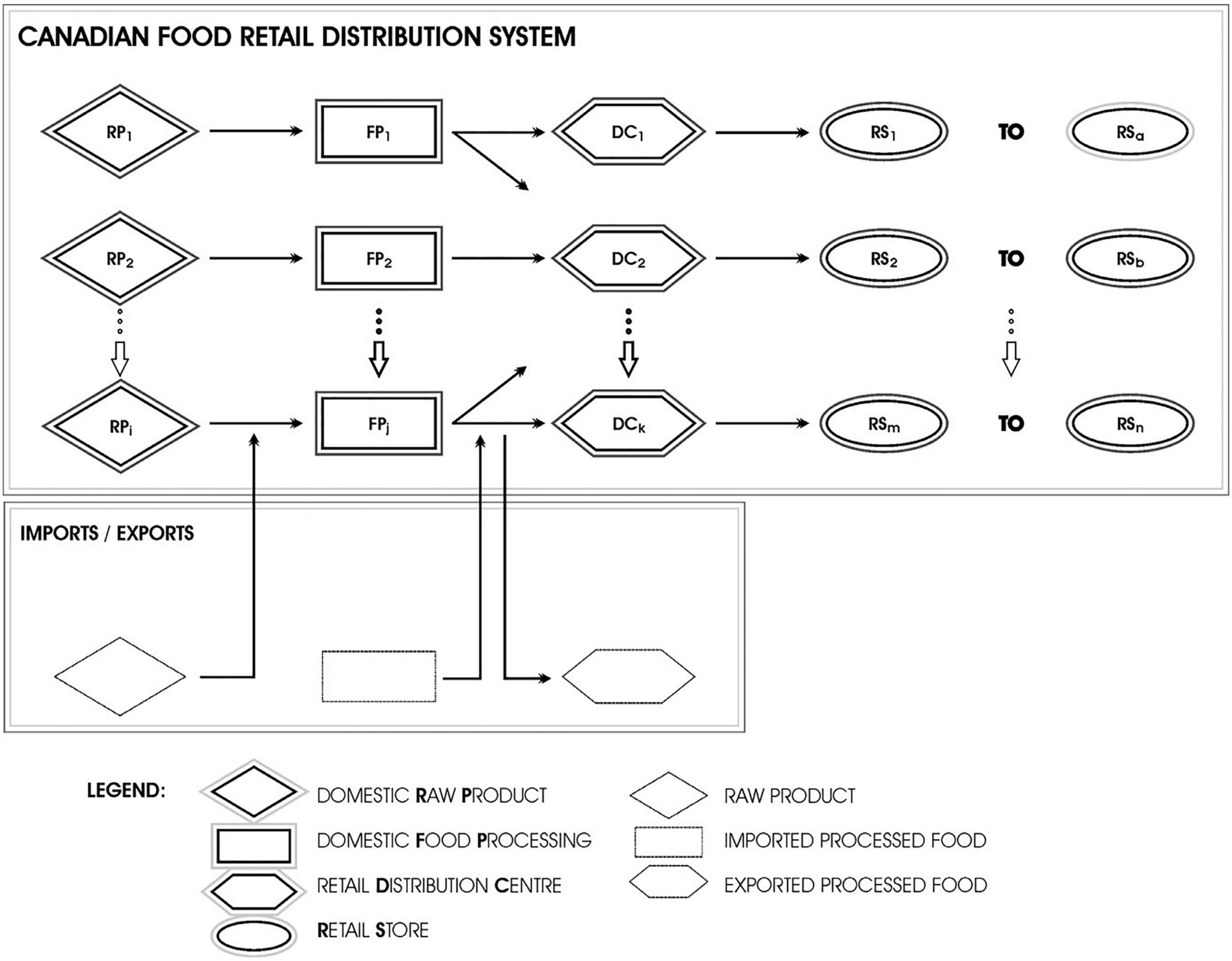

Fig. 4. Flowchart of the Canadian food supply chain.

remained below 5 °C, the minimum growth temperature for many foodborne pathogens such as *Escherichia coli* O157: H7. The lowest average temperature observed during storage at the distribution center, 2.0 °C, was sufficient to avoid freezing. In summer, higher temperatures were observed, especially during transportation. The average temperatures recorded during transportation from the processor to the distribution center, 6.3 °C, and from the distribution center to retail, 5.9 °C, were above the minimum growth temperature for foodborne pathogens such as *E. coli* O157: H7. Although brief, temperature peaks above 10 °C were also observed in summer, presumably during truck loading and unloading. The time-temperature profiles measured by McKellar et al. (2012, 2014) indicate that the winter performance of the cold chain is satisfactory but that shrinkage and pathogen growth due to higher temperatures along the cold chain could occur in summer.

The average total transportation time (sum of the transportation times from the processor to the distribution center and from the distribution center to retail) was approximately 55 h in winter and 22 h in summer for the ready-to-eat lettuce cold chain studied by McKellar et al. (2012, 2014). The average total transportation time was significantly longer in winter, possibly indicating seasonal variations in the origin or destination of the ready-to-eat lettuce, the road network used for transportation, or the transportation conditions. By way of comparison, Derens et al. (2006), Koutsoumanis et al. (2010), and Derens-Bertheau et al. (2015) reported average cold chain transportation times of approximately 5 h for dairy and meat products in France, 4 h for dairy products in Greece, and 8 h for meat products in France respectively. Similarly, Jacxsens et al. (2002) simulated spoilage of fresh-cut vegetables along a representative cold chain in Belgium and calculated a total average transportation time of 4 h. When compared with the measurements taken by McKellar et al. (2012, 2014), these results align with the expectation that transportation times are significant in Canada because of the long distances between cities. However, these transportation times are in accordance with those reported for the cold chain of berries in the United States (Nunes et al., 2014), which faces similar logistic issues related to the sparse population.

Emond et al. (2003) monitored the temperature, relative humidity and quality of a mixed shipment of fresh fruits and vegetables from Montreal to Nain, in the northern part of Labrador. The shipment was first transported for approximately 60 h by truck, and then placed on a 2-hour flight for its delivery to Nain. Significant temperature heterogeneities were observed, especially during transportation, with the temperature toward the front of the trailer being 13.3 °C, compared to 0.2 °C at the rear. Inspection of the load at the destination revealed the presence of multiple unmarketable products because of chilling injuries, water loss, bruises and browning. The low quality of the shipment was attributed to temperature heterogeneity and vibrations, as well as the challenges

Fig. 5. Map of the Canadian road and air transportation supply chain. Green areas are supplied by road. Red squares are entry points for air transportation. Areas outlined in blue are supplied by air from a single entry point. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

involved in delivering perishable food to northern communities, notably the harsh weather conditions and the shipment of mixed loads with different optimal temperatures.

Leblanc et al. (1996) measured the temperature of fruits and vegetables stored in display cabinets in 28 retail stores in Canada. The average temperature of the fruits and vegetables was 8 °C, above the recommended temperature of 4 °C. Similarly, Villeneuve et al. (2002) reported that the average temperature in a display cabinet used by a Canadian retail chain containing 150–200 kg of potatoes was 8.6 °C or 10.8 °C (for a set temperature of 4 °C) depending on whether the food rack was in the lower or upper part of the cabinet. The temperatures measured by Leblanc et al. (1996) and Villeneuve et al. (2002) were higher than those reported by McKellar et al. (2012, 2014) during storage at retail, a discrepancy that could be attributed to differences in the types of refrigeration systems used. Leblanc et al. (1996) reported that the temperature of the fruits and vegetables at the front of the display cabinets was on average 0.8 °C higher than the temperature of those at the back, and Villeneuve et al. (2002) reported that the temperature of the potatoes at the ends of the shelves in the display cabinet was 3.9 °C higher than the temperature of those in the middle of the shelves, indicating that the position of foods in a display cabinet has a significant impact on their temperature.

4.3. Foodborne infections

The incidence of foodborne illnesses is highly seasonal. A higher infection rate is observed in summer for many foodborne pathogens. Sari Kovats et al. (2005) investigated the seasonal pattern of infections with *Campylobacter* spp. in the province of Alberta from 1992 to 2000. A peak in the infection rate was observed in June and July: the infection rate during this period was more than double the rate seen in February and March. Similarly, Arsenault et al. (2012) studied infections with *Campylobacter* spp. in the province of Quebec from 1996 to 2006 and reported an infection peak in August, which had an infection rate approximately double the rate observed in winter. Fleury et al. (2006) examined infections with *Campylobacter* spp., *Salmonella* spp. and *E. coli* in the provinces of Alberta and Newfoundland and Labrador from 1992 to 2000 and observed significant infection peaks in summer. Michel et al. (2006) observed no seasonal pattern in infections with *Salmonella* Typhimurium phage type DT104 in Canada from 1999 to 2000, but they reported that 41% of infections with other phage types, including DT124 and DT208, occurred in summer, compared with 12% in winter. Nesbitt et al. (2012) reported that infections with *Salmonella* Enteritidis phage types PT13, PT8 and PT13a were significantly more frequent in summer than in winter in Canada from 2003 to 2009. The higher infection rate in summer for many foodborne pathogens can be attributed to a combination of numerous factors, including the possibility of the higher temperatures observed along the cold chain in summer promoting the growth of foodborne pathogens (McKellar et al., 2012, 2014). Additional factors that could increase the infection rate in summer include higher recreational exposure to water, increased environmental contamination by fertilization and animals in pasture, modifications to eating and travel habits, and variations in the amount and origin of imported foods (Michel et al., 2006).

In addition to the seasonal pattern of infections with foodborne pathogens, Fleury et al. (2006) showed that the infection rate is affected by the weekly ambient temperature. In the province of Alberta, the log relative risk of *Salmonella* spp., *Campylobacter* spp. and *E. coli* increased by 1.2%, 2.2% and 6.0% respectively for every increase of 1 °C in the weekly mean temperature. The increase in the infection rate as the ambient temperature rises could be attributed to the impact of ambient temperature on the growth rate of foodborne pathogens, and this finding confirms the critical impact of temperature on food safety along the cold chain.

4.4. Northern communities

Hundreds of small communities, each typically containing fewer than 1000 inhabitants, are scattered across the more than 4 million square kilometers of Canada's North (Nutrition North Canada, 2015). Many of these communities are isolated in the sense that they are not accessible year-round by road, rail or sea and are located far from major food distribution centers. Food insecurity is high in many of these communities. In recent surveys of communities in Nunavut, the Northwest Territories, northern Labrador, and northern Ontario, 69%, 43%, 46% and 70% of respondents respectively reported suffering some degree of food insecurity, a rate four to six times the national average (Rosol et al., 2011; Skinner, 2013; Council of Canadian Academies, 2014). The prevalence of food insecurity is attributed to high food prices, which are driven by high transportation and energy costs, high poverty levels, and food scarcity (Rosol et al., 2011; Council of Canadian Academies, 2014; Nutrition North Canada, 2015). A higher rate of food loss due to spoilage or shrinkage is also observed in northern communities. The percentage of food loss reported by retail stores in northern communities ranges from 5% to 20% (Nutrition North Canada, 2015). The high rate of food loss in these communities is explained by the lack of infrastructure (roads, refrigerated warehouses), the long distance to market, transportation delays due to weather conditions, the adverse environmental conditions (snow storm, fog, abundant rain and strong winds) and extreme temperatures (−50 °C during winter to 20 °C during summer), the inevitable use of mixed loads, inaccurate expiry dates, and the greater variance in demand associated with small markets (Emond et al., 2003; Nutrition North Canada, 2015). According to Emond et al. (2003), fresh fruits and vegetables may be exposed to extremely cold temperatures when shipped to northern communities. For example, within the northern community, distribution of the load to local retail stores involves the use of small sleighs pulled by snowmobiles without any kind of protection against wind, snow or rain; thus, the load is exposed directly to environmental conditions. Moreover, northern Aboriginal cultures value sharing, so community members typically do not store food, shop once for the week, or buy in bulk. This tradition is rooted in the practices of their ancestors, who were hunters and gatherers and took from the land only what they needed (Indian and Northern Affairs Canada, 2009).

The cold chain that supplies food to northern communities is highly complex, as it must deliver food to communities that are sparsely scattered, difficult to access and located in a challenging climate. The cold chain is community-specific, as each community has its own unique characteristics in terms of distance to market, accessibility, consumer income, population density, climate, and availability of country food. A concerted effort from each stakeholder in the cold chain is needed in order to identify, for each community, the most appropriate perishable foods, frequency of resupply, and systems for date labeling, transportation, and inventory management. Improving the cold chain could alleviate concerns about food security, quality, availability and cost and promote the accessibility of healthy food in northern communities.

Nutrition North Canada (NNC), a program implemented in 2011 and administered by Indigenous and Northern Affairs Canada, provides residents in 128 isolated northern communities with nutritious food at reduced cost. The NNC program provided $67.1 million in subsidies during its fourth year (2015–2016) in operation, as compared to $54.1 million during its first year (2011–2012). Between April 2011 and March 2015, the cost of the Revised Northern Food Basket (a pre-determined list of items) for a family of four (1 man and 1 woman aged 25–49 years, 1 boy aged 13–15 years, and 1 girl aged 7–9 years) was 5% lower on average than in March 2011, or approximately $94 per month (Nutrition North Canada, 2017a). Table 1 shows the amount of food products distributed between 2011–2012 and 2015–2016 through the NNC program for the top 8 categories (fruit and vegetables [fresh and frozen]); meat, poultry and fish (fresh and frozen); milk (fresh, UHT and canned evaporated); bread and bread products, cereals, crackers, flour and plain fresh and frozen pasta; cheese, yoghurt and other dairy products; unsweetened juice; eggs and egg substitutes; combination foods (fresh and frozen). In terms of the amount distributed by region, for 2015–2016, 38% and 24% ($ subsidy) went to the Baffin Region of Nunavut and Northern Quebec (Nunavik), respectively. Retailers with stores in northern communities received 92% of the products, while 3.5% was shipped to commercial establishments (hotels or restaurants), 2% to schools and daycares, and 2% to individuals (Nutrition North Canada, 2017b). Although the cost of the Revised Northern Food Basket decreased by 5% between April 2011 and March 2015, one weakness of the NNC program is that it is impossible to see whether the reported costs reflect the real costs of freight transport to communities since the actual freight costs paid by retailers and wholesale shippers are not disclosed (Galloway, 2014). The Auditor General of Canada also raised a number of concerns related to community eligibility and program management in the 2014 fall report (Office of the Auditor General of Canada, 2014). Program modifications may be necessary to achieve sustainable improvements to food security in northern communities (Galloway, 2017).

5. Research case study: development of the Canadian GIS-based risk assessment, simulation, and planning tool for food safety

The recently developed Canadian GIS-based Risk Assessment, Simulation, and Planning (CanGRASP) tool for food safety (Hashemi Beni et al., 2011, 2012; Leblanc et al., 2015) dynamically simulates the spatial distribution, at the national scale, of the public health

Table 1
Amount of food products distributed between 2011–2012 and 2015–2016 through the NNC program for the top 8 categories.

Product category	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	Average	% total
CAD$ of subsidy × 10^6 (kg of food × 10^6)							
Fruit and vegetables (fresh and frozen)	15.45	18.62	20.19	20.91	21.26	19.29	31.1
	(6.19)	(6.64)	(7.12)	(7.39)	(7.45)	(6.96)	(27.0)
Meat, poultry and fish (fresh and frozen)	9.30	10.96	11.09	11.38	11.51	10.85	17.5
	(3.99)	(4.16)	(4.19)	(4.31)	(4.37)	(4.20)	(16.3)
Milk (fresh, UHT and canned evaporated)	8.02	10.05	11.09	11.22	11.29	10.33	16.7
	(3.57)	(3.90)	(4.28)	(4.32)	(4.31)	(4.08)	(15.8)
Bread and bread products, cereals, crackers, flour and plain fresh and frozen pasta.	5.87	6.92	7.23	7.54	7.80	7.07	11.4
	(2.71)	(2.85)	(2.98)	(3.05)	(3.19)	(2.96)	(11.5)
Cheese, yoghurt and other dairy products	3.56	4.38	4.70	4.82	5.36	4.56	7.4
	(1.66)	(1.82)	(1.94)	(2.01)	(2.26)	(1.94)	(7.5)
Unsweetened juice	2.81	2.50	2.61	2.93	3.28	2.83	4.6
	(1.28)	(1.15)	(1.19)	(1.27)	(1.44)	(1.27)	(4.9)
Eggs and egg substitutes	2.17	2.54	2.65	2.71	2.75	2.56	4.1
	(1.09)	(1.06)	(1.10)	(1.13)	(1.14)	(1.11)	(4.3)
Combination of foods (fresh and frozen)	1.58	1.41	1.32	1.40	1.62	1.47	2.4
	(1.03)	(0.95)	(0.92)	(0.97)	(1.09)	(0.99)	(3.8)
Others	5.40	3.93	1.92	1.97	2.20	3.09	5.0
	(4.88)	(3.08)	(1.11)	(1.11)	(1.25)	(2.29)	(8.9)
Total	**54.16**	**61.32**	**62.82**	**64.88**	**67.07**	**62.05**	
	(26.40)	**(25.62)**	**(24.83)**	**(25.55)**	**(26.48)**	**(25.78)**	

risk associated with food contamination at any stage along the cold chain. It is based on the construction of relational databases that describe the flow and safety of food along the cold chain. For a given cold chain network, the databases describe the geographic location of the food processors, distribution centers and retail stores, the flow of food through the cold chain, the probability of products being exchanged between the various links in the cold chain, the distribution of temperature at each stage of the cold chain, and the transportation time (which is estimated from an analysis of the road network between the links of the cold chain). The databases provide the first detailed description of a cold chain network at a national scale (Leblanc et al., 2015). The flow and temperature of food along the cold chain is simulated from the databases using the Arena simulation tool. A public health risk index resulting from the contamination of food along the cold chain is calculated from the time-temperature history of the food, a foodborne pathogen growth model, and the density of the population around retail stores. The spatial distribution of the risk index caused by the contamination of the food is then dynamically mapped across Canada using ArcGIS.

CanGRASP can be used to trace foods during foodborne outbreaks, develop risk-mitigation measures for preventing or responding to outbreaks, and train stakeholders involved in public health risk assessment. In addition, since simulations of realistic contamination events are invaluable for identifying vulnerabilities along the cold chain, CanGRASP is a powerful integrated tool for improving the cold chain at the national level.

6. Improving tomorrow's cold chain: applying a GIS-based approach to improve food safety, quality and management

In recent years, as part of the European Food Refrigeration Innovations for Safety, consumers' Benefit, Environmental impact and Energy optimisation (FRISBEE) project, extensive databases detailing time-temperature profiles and energy consumption along cold chains of fruits, vegetables, seafood products, meat, and dairy products have been constructed (Gwanpua et al., 2015). The FRISBEE tool was developed to link the databases with quality and microbial growth models, simulate the safety and quality of perishable foods under realistic time-temperature conditions along the cold chain, and estimate the environmental impact of the cold chain. The tool provides a user-friendly graphical user interface (GUI) for investigating the impact of modifying the time-temperature profiles and refrigeration systems used along the cold chain. The tool can help improve cold chains through its multi-objective optimization module, which uses evolutionary algorithms to identify the cold chain conditions that minimize energy consumption and environmental impact and maximize food safety and quality.

Another relevant simulation tool, ALADIN^{TM} (Agro-Logistic Analysis and Design INstrument), was developed at Wageningen University (van der Vorst et al., 2009). The tool embeds sustainability indicators and food quality change models with logistic processes in discrete simulation models. The model captures the dynamic behavior of the food chain by modeling it as a network of agents, jobs, and flows with precedence relationships. Food chain network entities such as producers, distribution centers and retail outlets are represented as autonomous objects that are assigned decision-making intelligence (agents). The jobs are all food chain activities (physical jobs and control jobs), can be triggered by multiple causes and have outcomes and processing times that depend on the commodities processed and the available resources. Flow items include product flows, information flows, job definitions and resources for the transformation processes. Flow items represent the movable objects within the food chain. The advantages of this integrated model include the speed and quality of decision-making concerning food supply chain design. In addition to classical performance indicators such as stock levels, delivery reliability and transportation costs, ALADIN provide indications about energy use and CO_2 emissions as well as product quality. The benefits of the use of the ALADIN tool are illustrated in a case example (van der Vorst et al., 2009).

The limitation of the FRISBEE tool is its inability to simulate cold chains from a geographic description of their network, a capability offered by the CanGRASP tool. While the ALADIN tool takes into consideration the geographic position of the various supply chain entities in its scenarios, using simulations to model all configurations appears to be too time-consuming. By contrast, the drawbacks of the CanGRASP tool include the limited availability of data to estimate temperature conditions along the cold chain and the lack of data on the energy consumption and environmental impact of the cold chain. The CanGRASP and FRISBEE (or CanGRASP and ALADIN) approaches are in many ways complementary, and combining them seems like a natural way to produce a GIS-based tool that can dynamically map and calculate food safety, food quality, energy consumption, and environmental impact along the cold chain. The tool would provide a customizable approach for optimizing cold chain management for each network specific to a retail chain with a view to increasing food safety and quality and reducing energy consumption and environmental impact. This GIS-based tool would provide the most comprehensive approach possible to simulate cold chains and would be invaluable for evaluating exciting new developments in cold chain management, including quality distribution systems, dynamic expiry dates, and dynamic pricing, which have shown great potential for reducing waste and costs (Heising et al., 2017).

7. Conclusion

Stakeholders in the cold chain in Canada face significant challenges. The most notable challenge is the drastic seasonality of the cold chain, which necessitates strategies such as heating chilled foods in winter to avoid freezing injury. Additional challenges include the existence of community-specific cold chains, such as cold chains that deliver food to communities that are not accessible year-round by road, rail or sea, and the existence of market-specific cold chains, such as cold chains that deliver ready-to-cook meals using domestic delivery systems.

The available evidence supports the view that the cold chain successfully keeps the temperature of perishable foods within the desired range in winter, while improvements should be made to lower the temperature during transportation and processor storage in summer conditions. Since food security is a major issue in northern Canada, future cold chain research should also prioritize a detailed examination of the cold chains that deliver food to communities that lack year-round access by road, rail or sea.

The implementation and enforcement of proper regulations to ensure the delivery of safe and high-quality perishable food to consumers is a constant challenge shared by regulating institutions around the world. Given the intensive research activities involved in the preservation of perishable food, regulations must frequently be revisited to integrate new technologies and take into account evolving consumer behaviors. The establishment of proper regulations is further complicated by the global nature of the cold chain, creating the need for consistent regulations across countries while preserving market competitiveness.

Recent research projects offer exciting new prospects for improving the cold chain. Simulation tools are becoming increasingly comprehensive and accessible and provide an elegant alternative to costly experimental investigations for evaluating various cold chain management systems. Given the recent creation of extensive databases that describe cold chain networks, time-temperature conditions, energy consumption, and safety and quality models, the development of GIS-based simulation tools that provide a detailed dynamic and spatial description of cold chains is within reach and will offer valuable insight into the optimal cold chain for food safety, food quality and energy efficiency.

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References

Agriculture and Agri-Food Canada, 2015a. Statistical overview of the Canadian Fruit Industry—2014. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture/horticulture-canadian-industry/sector-reports/statistical-overview-of-the-canadian-fruit-industry-2014/?id=1447784197130 (accessed 02.02.2015).

Agriculture and Agri-Food Canada, 2015b. Statistical overview of the Canadian Vegetable Industry—2014. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture/horticulture-canadian-industry/sector-reports/statistical-overview-of-the-canadian-vegetable-industry-2014/?id=1448648029689#a3.1 (accessed 02.02.2015).

Agriculture and Agri-Food Canada, 2015c. Red meat trade balance reports. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/red-meat-and-livestock/red-meat-and-livestock-market-information/trade-balance/?id=1415860000005 (accessed 02.02.2015).

Agriculture and Agri-Food Canada, 2015d. Statistics Canada poultry and egg trade reports. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/poultry-and-eggs/poultry-and-egg-market-information/imports-and-exports/statistics-canada-poultry-and-egg-trade-reports/?id=1384971854405 (accessed 02.02.2015).

Agriculture and Agri-Food Canada, 2015e. Industry overview. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/fish-and-seafood/fish-and-seafood-canadian-industry/industry-overview/?id=1383756439917 (accessed 02.02.2015).

Agriculture and Agri-Food Canada, 2017. Red meat trade balance reports. Retrieved from: http://www.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/red-meat-and-livestock/red-meat-and-livestock-market-information/trade-balance/?id=1415860000005 (accessed 28.11.2017)

Arsenault, J., Michel, P., Berke, O., Ravel, A., Gosselin, P., 2012. Environmental characteristics associated with campylobacteriosis: Accounting for the effect of age and season. Epidemiol. Infect. 140, 311–322.

Brodt, S., Chernoh, E., Feenstra, G., 2007. Assessment of energy use and greenhouse gas emissions in the food system: A literature review. Retrieved from: http://asi.ucdavis.edu/programs/sarep/publications/ag-resources-enviro/litreview-assessmentofenergyuse.pdf/ (accessed 10.05.2016).

Canadian Dairy Information Centre, 2015. Canadian dairy trade bulletin. Retrieved from: http://www.dairyinfo.gc.ca/index_e.php?s1=pb&s2=trade (accessed 2.02.2015).

Canadian Food Inspection Agency, 2014. Food safety enhancement program manual. Retrieved from: http://www.inspection.gc.ca/DAM/DAM-food-aliments/STAGING/text-texte/food_fsep_man_1343667674768_eng.pdf (accessed 25.02.2016).

Canadian Food Inspection Agency, 2015. HACCP generic models and commodity-specific food safety guidance documents. Retrieved from: http://www.inspection.gc.ca/food/safe-food-production-systems/haccp-generic-models-and-guidance-documents/eng/1374992202076/1374992233926 (accessed 25.02.2016).

Canadian Food Inspection Agency, 2017. safe food for Canadians regulations. Retrieved from: http://www.inspection.gc.ca/about-the-cfia/acts-and-regulations/forward-regulatory-plan/2017-2019/sfcr/eng/1489788732771/1489788733189 (accessed 28.11.2017).

Chan, 2012. Canadian beef exports in rapid decline. Retrieved from: https://beta.theglobeandmail.com/report-on-business/canadian-beef-exports-in-rapid-decline/article4530972/?ref=http://www.theglobeandmail.com& (accessed 11.11.2017).

Coulomb, D., 2008. Refrigeration and cold chain serving the global food industry and creating a better future: two key IIR challenges for improved health and environment. Trends Food Sci. Technol. 19, 413–417.

Council of Canadian Academies, 2014. Aboriginal food security in Northern Canada: An assessment of the state of knowledge. Retrieved from: http://www.scienceadvice.ca/uploads/eng/assessments%20and%20publications%20and%20news%20releases/food%20security/foodsecurity_fullreporten.pdf (accessed 25.02.2016).

Derens, E., Palagos, B., Guilpart, J., 2006. The cold chain of chilled products under supervision in France. In: Proceedings of the IUFOST Thirteenth World Congress of Food Science & Technology: Food is Life. Nantes, France, pp. 51–64.

Derens-Bertheau, E., Osswald, V., Laguerre, O., Alvarez, G., 2015. Cold chain of chilled food in France. Int. J. Refrig. 52, 161–167.

Emond, J.-P., Mercier, F., Laurin, É., Nunes, M.C.N., 2003. Cold chain management of perishable distribution in northern communities of Canada. In: International Congress of Refrigeration. Washington, D.C. ICR0334, 7 pages.

Farm Credit Canada, 2014. Canadian agriculture and agri-food in the global economy 2013-14. Retrieved from: https://www.fcc-fac.ca/fcc/about-fcc/corporate-profile/reports/cage-report/cage-report-2013.pdf (accessed 25.02. 2016).

Fish Inspection Regulations, n. d. C.R.C., c. 802. Retrieved from: http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._802/index.html (accessed 28.11. 2017).

Fleury, M., Charron, D.F., Holt, J.D., Allen, O.B., Maarouf, A.R., 2006. A time series analysis of the relationship of ambient temperature and common bacterial enteric infections in two Canadian provinces. Int. J. Biometeorol. 50, 385–391.

Galloway, T., 2014. Is the nutrition North Canada retail subsidy program meeting the goal of making nutritious and perishable food more accessible and affordable in the North? Can. J. Public Health 105, e395–e397.

Galloway, T., 2017. Canada's northern food subsidy Nutrition North Canada: a comprehensive program evaluation. Int. J. Circumpol. Heal. 76, 1279451.

Garcia Martinez, M., Fearne, A., Caswell, J.A., Henson, S., 2007. Co-regulation as a possible model for food safety governance: Opportunities for public–private partnerships. Food Policy 32, 299–314.

Garnett, T., 2007. Food refrigeration: What is the contribution to greenhouse gas emissions and how might emissions be reduced? Retrieved from: http://www.fcrn.org.uk/sites/default/files/Refrigeration_paper_2007.pdf (accessed 10.05.2016).

Gwanpua, S.G., Verboven, P., Leducq, D., Brown, T., Verlinden, B.E., Bekele, E., Aregawi, W., Evans, J., Foster, A., Duret, S., Hoang, H.M., Van Der Sluis, S., Wissink, E., Hendriksen, L.J.A.M., Taoukis, P., Gogou, E., Stahl, V., El Jabri, M., Le Page, J.F., Claussen, I., Indergård, E., Nicolai, B.M., Alvarez, G., Geeraerd, A.H., 2015. The FRISBEE tool, a software for optimising the trade-off between food quality, energy use, and global warming impact of cold chains. J. Food Eng. 148, 2–12.

Hashemi Beni, L., Villeneuve, S., LeBlanc, D.I., Côté, K., Fazil, A., Otten, A., McKellar , R., Delaquis, P., 2012. Spatio-temporal assessment of food safety risks in Canadian food distribution systems using GIS. Spat. Spatiotemporal Epidemiol. 3, 215–223.

Hashemi Beni, L.H., Villeneuve, S., Leblanc, D.I., Delaquis, P., 2011. A GIS-based approach in support of an assessment of food safety risks. Trans. GIS 15, 95–108.

Heising, J.K., Claassen, G.D.H., Dekker, M., 2017. Options for reducing food waste by quality-controlled logistics using intelligent packaging along the supply chain. Food. Addit. Contam. A 34, 1672–1680.

Hertog, M.L.A.T.M., Uysal, I., McCarthy, U., Verlinden, B.M., Nicolaï, B.M., 2014. Shelf life modelling for first-expired-first-out warehouse management. Philos. Trans. R. Soc. A 372, 20130306.

Indian and Northern Affairs Canada, 2009. Summative evaluation of INAC's food mail program. Evaluation, performance measurement, and review branch audit and evaluation sector. Project Number:1570-7/07063. March 31, 2009. Retrieved at: https://www.aadnc-aandc.gc.ca/eng/1100100011721/1100100011735 (accessed 10.05.2016)

Jacxsens, L., Devlieghere, F., Debevere, J., 2002. Predictive modelling for packaging design: Equilibrium modified atmosphere packages of fresh-cut vegetables subjected to a simulated distribution chain. Int. J. Food Microbiol. 73, 331–341.

James, S.J., James, C., 2010. The food cold-chain and climate change. Food Res. Int. 43, 1944–1956.

Jedermann, R., Nicometo, M., Uysal, I., Lang, W., 2014. Reducing food losses by intelligent food logistics. Philos. Trans. R. Soc. A 372, 20130302.

Jol, S., Kassianenko, A., Oggel, J., Wszol, K., 2006. A country-by-country look at regulations and best practices in the global cold chain. Food Safety Magazine. Retrieved from: https://www.foodsafetymagazine.com/magazine-archive1/octobernovember-2006/a-country-by-country-look-at-regulations-and-best-practices-in-the-global-cold-chain/ (accessed 28.11.2017).

Jol, S., Kassianenko, A., Wszol, K., Oggel, J., 2007. The cold chain, one link in Canada's food safety initiatives. Food Control 18, 713–715.

Koutsoumanis, K., Pavlis, A., Nychas, G.-J.E., Xanthiakos, K., 2010. Probabilistic model for *Listeria monocytogenes* growth during distribution, retail storage, and domestic storage of pasteurized milk. Appl. Environ. Microbiol. 76, 2181–2191.

LeBlanc, D.I., Stark, R., MacNeil, B., Gopen, B., Beaulieu, C., 1996. Perishable food temperatures in retail stores. In: *New Developments in Refrigeration for Food Safety and Quality*, Refrigeration Science and Technology Proceedings of the Meeting of Commission C2, with Commissions B2, D1, and D2-3. Lexington, Kentucky, USA. International Institute of Refrigeration, pp. 42–51.

Leblanc, D.I., Villeneuve, S., Beni, L.H., Otten, A., Fazil, A., McKellar, R., Delaquis, P., 2015. A national produce supply chain database for food safety risk analysis. J. Food Eng. 147, 24–38.

McKellar, R.C., LeBlanc, D.I., Lu, J., Delaquis, P., 2012. Simulation of *Escherichia coli O157:H7* behavior in fresh-cut lettuce under dynamic temperature conditions during distribution from processing to retail. Foodborne Pathog. Dis. 9, 239–244.

McKellar, R.C., LeBlanc, D.I., Rodríguez, F.P., Delaquis, P., 2014. Comparative simulation of *Escherichia coli O157: H7* behaviour in packaged fresh-cut lettuce distributed in a typical Canadian supply chain in the summer and winter. Food Control 35, 192–199.

Meat Inspection Regulations, 1990. SOR/90-288. Retrieved from: http://laws-lois.justice.gc.ca/eng/regulations/SOR-90-288/index.html (accessed 28.11.2017).

Michel, P., Martin, L.J., Tinga, C.E., Doré, K., Fyfe, M., Buxton, J., King, A., Paccagnella, A., Grimsrud, K., Zazulak, I., Talbot, J., Rennie, R., Pieroni, P., Ahmed, R., Rodgers, F., Pollari, F., Doré, K., Wilson, J., Michel, P., Middleton, D., Naus, M., Henry, B., Cieben, B., Jamieson, F., 2006. Regional, seasonal, and antimicrobial resistance distributions of *Salmonella* Typhimurium in Canada: A multi-provincial study. Can. J. Public Health 97, 470–474.

Nesbitt, A., Ravel, A., Murray, R., McCormick, R., Savelli, C., Finley, R., Parmley, J., Agunos, A., Majowicz, S.E., Gilmour, M., 2012. Integrated surveillance and potential sources of *Salmonella Enteritidis* in human cases in Canada from 2003 to 2009. Epidemiol. Infect. 140, 1757–1772.

Nunes, M.C., Nicometo, M., Emond, J.P., Melis, R.B., Uysal, I., 2014. Improvement in fresh fruit and vegetable logistics quality: Berry logistics field studies. Philos. Trans. R. Soc. A 372, art no. 20130307.

Nutrition North Canada, 2015. Northern Food retail data collection & analysis by Enrg Research Group. Retrieved from: http://www.nutritionnorthcanada.gc.ca/eng/1424364469057/1424364505951 (accessed 25.02.2016).

Nutrition North Canada, 2017a. Results from 2011-2016. Retrieved from: http://www.nutritionnorthcanada.gc.ca/eng/1415649594068/1415649613120 (accessed 10.11.2017).

Nutrition North Canada, 2017b. 2015-2016 Full fiscal year. Retrieved from: http://www.nutritionnorthcanada.gc.ca/eng/1491402892387/1491402911878 (accessed 10.11.2017).

Office of the Auditor General of Canada, 2014. Report of the Auditor General of Canada. Chapter 6—Nutrition North Canada—Aboriginal Affairs and Northern Development Canada. Retrieved from: http://www.oag-bvg.gc.ca/internet/English/parl_oag_201411_06_e_39964.html (accessed 10.11.2017).

Prentice, B.E., McLachlin, R., 2008. Refrigerated food transport from Canada to Mexico: Cold chain challenges. J. Transp. Res. Forum 47 (2), 119–131.

Quigley, K., 2014. Analysis of the Regulatory Regime for Controlling Risks Related to the Canadian Food Supply Chain. Ph.D. thesis. Dalhousie University.

Rodrigue, J.P., 2014. Reefers in North American cold chain logistics: Evidence from western Canadian supply chains. Retrieved from: http://vanhorne.info/files/vanhorne/reefers-in-north-american-cold-chain-logistics-evidence-from-western-canadian-supply-chains.pdf (accessed 25.02.2016).

Rosol, R., Huet, C., Wood, M., Lennie, C., Osborne, G., Egeland, G.M., 2011. Prevalence of affirmative responses to questions of food insecurity: International Polar Year Inuit Health Survey, 2007-2008. Int. J. Circumpol. Heal. 70, 488–497.

Sari Kovats, R., Edwards, S.J., Charron, D., Cowden, J., D'Souza, R.M., Ebi, K.L., Gauci, C., Gerner-Smidt, P., Hajat, S., Hales, S., Hernández Pezzi, G., Kriz, B., Kutsar, K., McKeown, P., Mellou, K., Menne, B., O'Brien, S., van Pelt, W., Schmid, H., 2005. Climate variability and campylobacter infection: an international study. Int. J. Biometeorol. 49, 207–214.

Skinner, K., 2013. Prevalence and Perceptions of Food Insecurity and Coping Strategies in Fort Albany First Nation. Ph.D. thesis. University of Waterloo, Ontario.

Statistics Canada, 2007. Weather conditions in capital and major cities (Temperatures). Retrieved from: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys08b-eng.htm (accessed 10.05.2016).

Statistics Canada, 2017. Canadian International Merchandise Trade Database. Retrieved from: http://www5.statcan.gc.ca/cimt-cicm/topNCommodity-marchandise?lang=eng&getSectionId()=0&dataTransformation=0&scaleValue=0&scaleQuantity=0&refYr=2016&refMonth=9&freq=12&countryId=999&getUsaState()=0&provId=1&retrieve=Retrieve&country=null&tradeType=3&topNDefault=25&monthStr=null&chapterId=2&arrayId=9800002&sectionLabel=I%20-%20Live%20animals%20and%20animal%20products. (accessed 28.11.2017).</bib>

U.S. Public Health Service, 2013. Food code. Retrieved from: https://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM374510.pdf (accessed 28.11.2017).

Van der Vorst, J.G.A.J., Tromp, S.-O., van der Zee, D.-J., 2009. Simulation modelling for food supply chain redesign; integrated decision making on product quality, sustainability and logistics. Int. J. Prod. Res. 47 (23), 6611–6631.

Villeneuve, S., Émond, J.P., Mercier, F., Nunes, M.C.N., 2002. Analyse de la température de l'air dans un comptoir réfrigéré. Revue générale du froid 1025, 17–21.

Young, L., 2012. Our biggest problem? We're wasting food. Retrieved from: http://www.canadiangrocer.com/top-stories/what-a-waste-19736 (accessed 10.05.2016).