The decline in Shiga toxin producing Escherichia coli illness in Canada: evidence for a role in changes in beef industry practices

Alex Gill

Health Canada, Bureau of Microbial Hazards
email: alex.gill@canada.ca; Telephone: 613-957-2924; Fax: 613-941-0280

Shiga toxin producing Escherichia coli (STEC), including Escherichia coli O157:H7, was the sixth most commonly reported cause of foodborne illness in Canada in 2014, the most common was Salmonella enterica (PHAC, 2016). However, public awareness, particularly of E. coli O157:H7 is higher than for other more common foodborne pathogens, such as viruses (2nd) and parasites (3rd). The involvement of E. coli O157:H7 in a number of high profile outbreaks involving beef products, particular ground beef patties, has resulted in the use of the popular term 'hamburger disease'. This association between the pathogen and beef, and the regulatory response to this issue, has had a significant impact on the evolution of the practices of the North American beef industry. These changes in industry practice have occurred during a period in which reported STEC illness in Canada, including E. coli O157, has fallen from an average of 4.5 per/100,000 in the period of 1993-1999 to an average of 1.8 per/100,000 in the period of 2009 to 2019 (Figure 1) (PHAC, 2017). In a recently published study Pollari et al. (2017) presented evidence of a correlation between changes in the practices of the Canadian beef industry and the reduction in reported STEC illness. In this paper I present a summary of the report of Pollari et al. (2017) and discuss the implications of the coincident trends identified.

Escherichia coli is a common bacterium that colonises many animals and can be isolated from a wide range of environments (Persad and LeJeune, 2014). Most E. coli strains are not pathogenic but some strains possess specific virulence factors which make them pathogens. The E. coli pathogens of the greatest public health significance in Canada and the United States of America (US) are STEC, which are also known as verotoxin producing E. coli. The public health significance of STEC can be attributed to three factors; the low infectious dose, estimated at less than 100 cells (Todd et al., 2008); the risk of severe and potentially life threatening disease (Karpman and Ståhl, 2014); and limited treatment options (Agger et al., 2015). Several hundred STEC serotypes have been reported (Bettelheim 2007), but the most commonly reported serotype in Canada and the US is E. coli O157:H7 and its non-motile variant E. coli O157:NM (E. coli O157). STEC O157 accounted for 71% of STEC isolates reported to the Public Health Agency of Canada in 2014 (PHAC, 2016), and 36.6% of STEC illnesses reported in the US in 2015 (CDC 2017a).

Though STEC outbreaks have been caused by a wide range of contaminated food, of both plant and animal origin, historically the food most commonly associated with STEC outbreaks in the US has been beef. Beef consumption was associated with 27% of 544 outbreaks involving STEC from 1998 to 2017 reported to the Centers for Disease Control (CDC 2017b). The association of STEC with beef is a consequence of two factors. Firstly, STEC, including E. coli O157, commonly colonise the gastro-intestinal tract of cattle and are not associated with disease in adult cattle (Gill and Gill, 2010). Secondly, STEC in the feces of cattle can contaminate the hide of incoming cattle, so STEC along with other microbiota from the gastro-intestinal tract and hide may contaminate meat during the processes of slaughter and carcass breaking (Gill and Gill 2010).

The single most significant event in the history of STEC and the North American beef industry was undoubtedly the 1993 outbreak of E. coli O157 involving beef patties sold by the US restaurant chain Jack in the Box. Though E. coli O157 outbreaks associated with beef had been previously reported there were features of this outbreak which generated significant public attention and a demand for a regulatory response in the US. The outbreak was large, with over 500 laboratory confirmed cases, the outbreak continued over a prolonged period (4 months), and many of the patients were young children, including 38 with serious kidney problems and 4 tragic deaths (CDC, 1993). Finally, litigation arising from the outbreak established US precedents for legal liability and victim compensation.

Following the 1993 Jack in the Box outbreak, in 1994 the US Department of Agriculture Food Safety and Inspection Service (FSIS) declared E. coli O157 to be an adulterant in non-intact beef, including beef trim, which is commonly used as precursor for raw ground beef. This designation provided the FSIS legal authority to remove products from the market that were known to be contaminated with the pathogen and later to institute testing programs for E. coli O157, and a requirement for US federally inspected slaughter works and processors to maintain a Hazard Analysis and Critical Control Point (HACCP) plan to control E. coli O157. In 2011, the FSIS declared six additional STEC serogroups (O26, O45, O103, O111, O121, O145) to be adulterants in non-intact beef, and subsequently established testing programs for these pathogens.

This regulatory response to STEC in the US necessarily impacted the Canadian beef industry as the US was, and remains, the primary export market for Canadian beef. In the year ending September 2017, exports to the US accounted for 74% of both dollar value and volume of product of all Canadian beef and veal exports (AAFC 2017). Thus, though there are significant differences in the regulatory approach to STEC as a foodborne illness in Canada, the importance of market access to the US should be understood as a crucial driver of changes in Canadian beef industry during this period. US import requirements have included testing for E. coli O157, and since 2011 other STEC, in imported raw ground beef and precursor material, and the maintenance of a HACCP plan by exporting facilities. These US requirements have been supplemented by Canadian requirements for all federally-registered establishments to have a HACCP plan (since 2004) and to conduct testing of raw ground beef precursor material for E. coli O157 (CFIA, 2017). Additionally, the Canadian Food Inspection Agency (CFIA) conducts its own testing for the presence of E. coli O157 and generic E. coli >100 CFU/g in raw ground beef and trim.

While there are a large number of facilities involved in beef slaughter and processing in Canada the share of total production at the majority of these facilities is very low. The majority of production occurs at three large plants which are estimated to account for 89% of beef slaughter and ground beef precursor material production (Pollari et al., 2017). Consequently, changes in industry practice at these three large plants have the greatest potential to impact STEC exposure from beef in Canada.

The industry response to E. coli O157 and other STEC has included plant modernisation and progressive improvements to process hygiene through changes to equipment, personnel training, and practices (Duckworth, 2013). These incremental changes are difficult to document and quantify. However, data is available from the three large plants indicating the commitment to invest in reducing STEC contamination. A survey was conducted by the Canadian Meat Council of the number of interventions to reduce bacterial contamination along the processing line in the three large plants, from 1996 to 2014. Since 1996, these three large plants have consistently invested in a greater number of interventions, rising from a total of 1 intervention in 1996, to 54 implemented across the three plants in 2014 (Figure 2).

The effectiveness of changes in industry practice in improving processing hygiene is supported by evidence of reduced contamination of beef with STEC and generic E. coli. The CFIA has conducted testing of ground beef and trim for the presence of E. coli O157 and generic E. coli greater than 2 log CFU/g since 2001. From the 2001/2002 sampling year to the 2013/2014 sampling year the prevalence of E. coli O157 positive samples and generic E. coli samples greater than 2 log CFU/g has followed a downward trend from 0.83% to 0% (E. coli O157) and from 4.5% to 2.3% (generic E. coli). A decline in the frequency in all STEC serotypes in retail beef is evident from Canadian studies published in 1990 and 2000 which reported STEC prevalence rates of 33% to 36% (Read et al., 1990; Atalla et al., 2000) to an average prevalence rate of 1.82% from 2012 to 2015 (Pollari et al., 2015).

The hypothesis of Pollari et al. (2107) that changes in beef industry practice over the last 20 years have contributed to a reduction in STEC illness in Canada is supported by three coincident trends; a reduction in the rate of STEC illness; a reduction in ground beef contamination with STEC; and increasing industry investment in STEC control by the beef industry. That the observed reductions in STEC illness and beef contamination is due to reduced STEC carriage by cattle can be excluded by the absence of evidence of such a reduction (Pollari et al., 2017). The observed reduction in rates of STEC illness may also be a consequence of changes in the production practices of other foods, such as fresh produce, where there is risk of STEC exposure, and changes in consumer behaviour in response to the food safety education programs conducted by provincial and federal public health partners.

Unfortunately, it is not possible to identify the specific changes in practice or interventions which have contributed most significantly to reducing STEC contamination of beef. However, the available data does provide some insight into the role of pathogen testing in reducing STEC contamination. It is commonly assumed that testing raw ground beef and precursor material for E. coli O157 primarily serves to reduce consumer exposure by filtering out of the distribution chain production lots that are contaminated. If the impact of testing on beef safety was primarily to filter out contaminated product, it would be expected that the prevalence of retail ground beef samples positive for E. coli O157 would have declined, while the prevalence of unsatisfactory lots of ground beef and precursor material at the processor would have remained static. But this is not consistent with the observations presented by Pollari et al. (2017).

In addition to acting to filter contaminated product out of the food chain it has been suggested by US Department of Agriculture economists Ferrier and Buzby (2014) that pathogen testing acts as a stimulus to improved process hygiene by imposing an economic cost on the processor. Positive lots represent an economic loss, as a result of their destruction or diversion to cooking. In response to this economic signal the processor changes practices to minimise economic losses resulting from positive lots. The hypothesis that the success of testing programs results from their role in driving improved process hygiene is consistent with the trends described by Pollari et al. (2017). If filtering is the primary effect of testing it will provide rapidly diminishing returns on effort. Sampling of raw ground beef and precursor material for testing for STEC is conducted using an n60 sampling plan. For an n60 sampling plan the acceptance rate for a contaminated lot is 5% when the contamination frequency is 5%, if the contamination frequency drops to 2% the acceptance rate increases to 30% (Gill and Gill 2015).

While the apparent success of the Canadian beef industry and regulators in reducing STEC contamination of beef is an accomplishment worthy of celebration, two important questions remain. Firstly, the specific interventions and changes to practices which have been most cost-effective in improving product hygiene have not been identified. There is a risk that industry may not be allocating resources to STEC prevention in the most cost effective manner. This is an issue which is probably best addressed by research within the specific context of individual facilities. Secondly, if the hypothesis is correct, that the stimulus driving industry improvements has been the economic signal provided testing for E. coli O157 and other STEC then this is an issue that needs further examination. STEC testing of beef is a time consuming process and expensive private and publicly funded infrastructures have been built up to support it. The question then should be asked whether there are more cost effective mechanisms for generating the required signals and driving industry to improve product safety. If such mechanisms can be identified and implemented in collaboration between industry and regulators then there is a potential for improved food safety at reduced cost to both public and private sectors.

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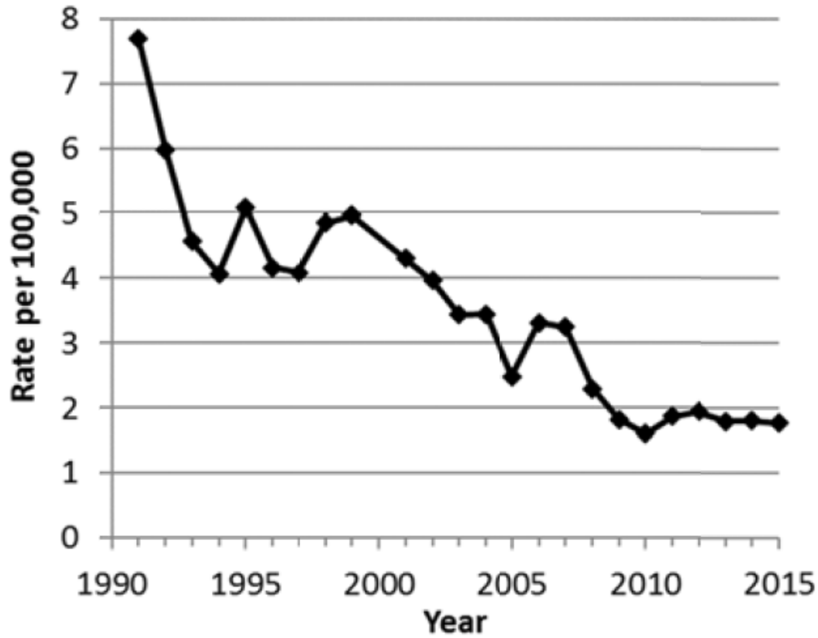

Figure 1. Rate of Shiga toxin producing *Escherichia coli* illness reported per 100,000 inhabitants in Canada from 1991 to 2015 (PHAC 2017). Data from the year 2000 is omitted to exclude the 2,300 cases from the waterborne outbreak in Walkerton, ON.

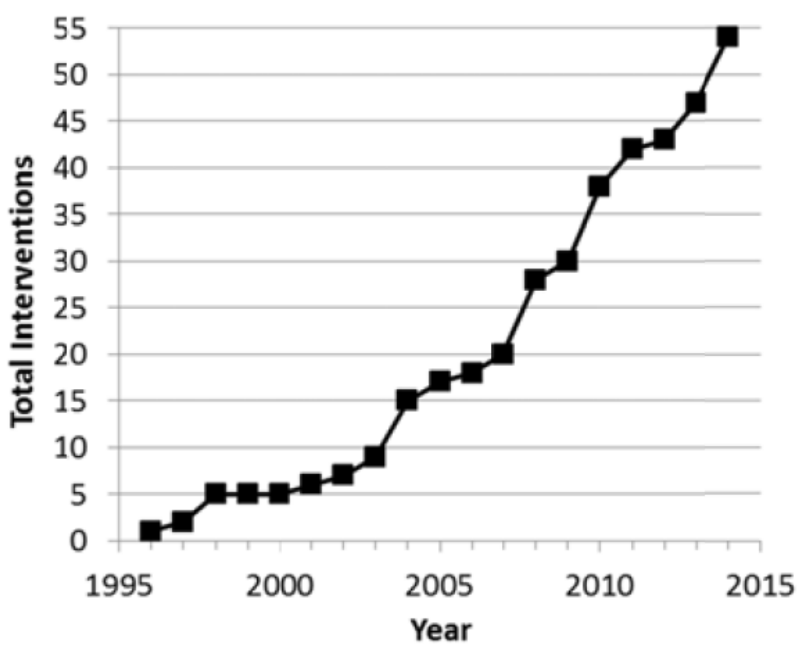

Figure 2. Annual sum of processing interventions for the reduction of bacterial contamination employed at the three Canadian beef processing plants that process 89% of Canadian beef. (Pollari et al., 2007)