Reducing the Public Health Risk of *Escherichia coli* O157 Exposure by Immunization of Cattle

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ABSTRACT

The One Health approach investigates the complexities surrounding the interplay between the animal, human and environmental domains. Zoonotic pathogens, such as *Escherichia coli* (*E. coli*) O157, which have animal reservoirs, also have direct impact on public health. Cattle are the primary reservoir of *E. coli* O157, however infection with this bacterium is asymptomatic. Infected cattle appear healthy and have normal growth rates and milk production abilities. Each year, thousands of Canadians become ill following exposure to *E. coli* O157. To reduce this public health risk, immunization of cattle would be an effective intervention. Several models have shown that on-farm pathogen reduction programs would significantly reduce the risk of human illness.

KEY WORDS: *E. coli* O157; One Health; pre-harvest

La traduction du résumé se trouve à la fin de l'article.

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Many new and emerging diseases are zoonotic, meaning they can be transmitted from animals to humans.¹ The One Health approach addresses better control of these pathogens by recognizing connections between the animal, human and environmental domains.

There are many different strains of *Escherichia coli* (*E. coli*) that live in the human intestine and cause no disease. However, one Enterohemorrhagic *E. coli* serotype, O157, which often resides in cattle, releases toxins that can cause severe illness in humans, and only a small number (fewer than 10 bacteria) are required to cause serious human illness.² While there are numerous verotoxigenic *E. coli* serotypes, O157 is most frequently associated with human illness.² In addition to outbreaks caused by contaminated meat, human exposure to *E. coli* O157 is regularly traced to contaminated fruits and vegetables; unpasteurized milk and fruit juice; potable and recreational water such as lakes, rivers and streams; and animals at fairs, exhibitions and petting zoos (through direct contact).²

Symptoms of primary illness begin 3-10 days after infection with *E. coli* O157 bacteria and range from diarrhea and fever to severe bloody diarrhea to Haemolytic Uremic Syndrome and death.² Long-term studies following patients infected with *E. coli* O157 have documented secondary illnesses due to hypertension, cardiovascular and kidney disease as well as arthritis.³ Many steps have been taken along the farm-to-fork continuum to reduce the risk of infection from *E. coli* O157, such as consumer education about food handling practices, better retail and transport refrigeration, test and hold procedures at the processing stage, and hide washes and carcass pasteurization during harvest. Currently, little is being done on the farm to reduce *E. coli* O157 prevalence prior to harvest. As part of a multiple-hurdle approach, more can be done at this stage to further reduce the public health risk of illness due to *E. coli* O157. Recent developments in cattle vaccination against *E. coli* O157 may offer a solution.

E. coli O157 colonizes in the intestines of cattle and has not been associated with clinical disease of the carrier animal.² The bacterium is shed in the feces, and manure from beef and dairy farms, used as a fertilizer for crops, is a source of contamination for the general environment as well as for surface and ground water.

Epidemiological studies indicate there is an association between higher rates of *E. coli* O157 human infection and areas associated with higher cattle densities.⁴ A review of existing studies demonstrates prevalence rates of animals testing positive for *E. coli* O157 ranging from 9% to 88%. This wide range exists both within and between herds and results from several factors, such as season (prevalence is higher in summer than in winter), environmental conditions, and conditions in the feedyard.^{2,5}

The United States Department of Agriculture (USDA) Food Safety Inspection Service Risk Modelers studied the relationship among seasonal occurrence of *E. coli* O157 in cattle, ground beef, and human illness.⁶ Their investigation supports the theory that an increased shedding of *E. coli* O157 by cattle in the summer season is associated with an increased prevalence of this organism in ground beef and a corresponding increase in number of human illnesses.

Published data show immunization of cattle to decrease the *E. coli* O157 seasonal prevalence spike from April to October.⁵ Data also show that cattle vaccination decreases shedding of *E. coli* O157,

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Table 1. Percent Reduction in Average Probability of Illness per Serving Associated With Pre-harvest Interventions^{10*}

Comparison	Type of Beef	Probiotic†	SRP Vaccine‡	Type III Protein Vaccine§
Risk reduction associated with pre-harvest intervention and current practices in Canada compared to current Canadian practices only	Ground beef	57%	56%	78%
	Non-intact cuts	27%	54%	65%
	Intact cuts	5%	61%	84%

* Data derived from reference 10, Table 9.

† The Probiotic is a lactobacillus culture fed to cattle. It is available in the United States and is an unregulated product not approved for use in Canada. Additional information can be found at <http://www.bovine.com/>.

‡ The Siderophore Receptor/Porin proteins-based vaccine (SRP Vaccine) is available in the United States for use under a conditional license granted by the United States Department of Agriculture but not approved for use in Canada. Additional information can be found at http://www.epitopix.com/srp_vaccines.asp.

§ The Type III Protein Vaccine is fully licensed and available in Canada. Additional information can be found at <http://www.econichevaccine.com/>.

|| Current practices in Canada include a pre-evisceration hot water wash, a post-evisceration wash, and water or acid spray during chilling.

which reduces the risk of human illness.⁶ By reducing colonization and shedding, vaccination also reduces the probability for environmental transmission of *E. coli* O157 within commercial farm operations, thus gradually limiting the re-infection cycle within the herd.⁷ Modeling by Matthews et al. predicts that interventions aimed at preventing high bacterial loads could be highly effective strategies for reducing prevalence of *E. coli* O157.⁸

In 2008, the Canadian Food Inspection Agency (CFIA) fully licensed a vaccine for immunization of healthy cattle as an aid in the reduction of shedding of *E. coli* O157. To reduce the public health risk associated with exposure to *E. coli* O157, vaccination of cattle across the various industry segments (beef, dairy, organic, cow-calf) should be implemented. Such an approach is supported by results of a recent study indicating that cattle vaccination is considered the most effective measure to reduce human exposure to *E. coli* O157.⁹ This can be completed concurrently with routine vaccination practices related to herd health management.

The USDA Food Safety Inspection Service investigated the economic outcomes of pre-harvest vaccination strategies based on vaccine efficacy and coverage.⁵ The model investigated the economic break-even point, factoring in multiple prices per dose of vaccine, vaccine efficacy and herd immunity levels. Withee et al. determined that, depending on vaccine efficacy, it would be a cost-effective intervention in preventing *E. coli* O157 human illness, at a price per unit between \$2.29 and \$9.14 USD.⁵

Similarly, using quantitative risk assessment methodology, Smith et al. investigated the public health risks in Canada associated with *E. coli* O157 contamination in ground beef, non-intact beef (tenderized) and intact beef.¹⁰ The authors focused on risk reduction arising from the use of various combinations of pre-harvest and processing interventions and its impact on public health. Based on their analysis, the most effective approach is to include vaccination of cattle using the Canadian licensed product as a pre-harvest step in conjunction with multiple interventions throughout the chain. The current risk reduction scenario is based on the use of pre-harvest interventions, presented in Table 1. Vaccination of cattle with the product licensed by CFIA provided maximal risk reduction. According to Smith et al., the average number of illnesses per million servings of cooked ground beef would be reduced from 8 with current practices to less than 1 by combining pre-harvest vaccination of cattle with the product licensed by CFIA together with enhanced post-harvest processing practices.

Ellis-Iversen et al. found that most UK farmers accepted ownership of their role in food safety, and that producers with on-farm control measures associated these actions with consumer demand and profitability.¹¹ Younger farmers and larger producers were more likely to believe financial responsibility to be an industry-wide duty; and the veterinarian is typically considered the preferred motivator.

A survey indicated that Canadian producers believe *E. coli* O157 food-borne illnesses and beef recalls are a genuine threat to the health of their industry.¹² A majority of producers expressed sensitivity about the cost of the vaccine, which is approximately \$3 per dose. Producers, however, also expressed an overwhelming willingness (88%) to vaccinate their cattle, provided the vaccine was provided at no cost or if they received offsetting revenue.

Various Canadian industry associations and government departments, such as The Beef Value Chain Roundtable and the Association of Bovine Veterinarians, have expressed support for strategies that eliminate or reduce *E. coli* O157.¹³ The Government Standing Committees of Finance and Agriculture have likewise recommended the funding, development and implementation of a program designed to ensure the removal or reduction of *E. coli* from the Canadian food chain.¹⁴

Guidance has been issued by the USDA's Food Safety Inspection Service, recommending that slaughter facilities obtain cattle that have received one or more pre-harvest interventions to reduce shedding of *E. coli* O157.¹⁵ An alternate approach is being considered in Sweden, where experts are developing a national on-farm *E. coli* O157 control program.¹

Globally, the contamination of meat, vegetables, fruits and water as a result of exposure to *E. coli* O157 from livestock manure is a threat to public health. Preventing infections in people requires control measures at all stages of the food chain, from agricultural production on the farm to the processing, manufacturing and preparation of foods in commercial establishments and in the home. Cattle are routinely immunized against common bovine pathogens to prevent infection and disease. Incorporation of an additional vaccine to reduce a public health risk would easily fit into existing herd health management protocols within all production systems. The majority of reported outbreaks with verotoxigenic *E. coli* are due to the O157 serotype. Evidence indicates that other serotypes such as O26, O111, O103, O121, O45 and O145 contribute to human illness.² Data clearly show that vaccination of cattle with the *E. coli* O157 Type III protein or the SRP vaccine decreases *E. coli* O157 shedding. To the best of the authors' knowledge, data demonstrating efficacy of either vaccine on non-O157 serotypes in cattle is not yet available.

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RÉSUMÉ

L'approche « Une seule santé » porte sur l'action réciproque complexe entre les domaines animal, humain et environnemental. Les agents pathogènes zoonotiques comme *Escherichia coli* (E. coli) O157, qui ont des réservoirs animaux, ont aussi un impact direct sur la santé publique. Les bovins sont le principal réservoir d'E. coli O157, mais l'infection par cette bactérie est asymptomatique. Les bovins infectés semblent en bonne santé et ont des taux de croissance et des capacités de production laitière normaux. Chaque année, des milliers de Canadiens tombent malades après avoir été exposés à E. coli O157. La vaccination des bovins serait une mesure efficace pour réduire ce risque pour la santé publique. Plusieurs modèles ont montré que les programmes de réduction des agents pathogènes dans les élevages réduiraient significativement le risque de maladie chez les humains.

MOTS CLÉS : *Escherichia coli* O157; Une seule santé; pré-récolte