

Methods to reduce the risk of *E.coli* O157:H7 shedding in cattle

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Background

E. coli O157:H7 belongs to the Shiga toxin-producing *E. coli* (STEC) and is a bacterium that often colonizes the guts of cattle, although many animal species harbor it in their digestive tract. There are other STECs besides *E. coli* O157:H7, although much less studied, and the terms are used interchangeably here. This pathogen can cause serious disease in people, especially in the elderly, children or immune-compromised. Cattle shedding STEC, on the other hand, do not show signs of disease because they lack the receptor that binds the toxin produced by the pathogen. People get exposed through various routes, such as direct contact with animals or infected persons or through water sources, but the most important route is via contaminated food [1]. Some of the foods most commonly associated with *E. coli* infections are ground beef as well as vegetables, such as Romaine lettuce, which was implicated in one of the most recent outbreaks in the US [2]. Interventions at the slaughter plant and consumer education about properly cooking meat have led to a decrease in the number of cases of human STEC infections over the past 20 years [3]. Nevertheless, there is some concern that cattle may be a possible source of STEC contamination of vegetable crops [4]. Strategies to prevent fecal shedding of STEC in live cattle is therefore desirable to complement food safety measures at the slaughter plant and during food preparation. The pathogen lives both in the environment as well as in the host and cattle shed STEC at different rates depending on factors such as ambient temperature or diet [5]. So-called super-shedders, i.e. cattle shedding at least 1000 colony forming units (CFU) / g of feces, play an important role in transmission among cattle, but the mechanisms that lead to super-shedding are not well understood [6]. Possible targets for reduction of STEC shedding are thus the environment and the guts of cattle. Vaccines targeted at *E. coli* O157:H7 have been explored as a means of reducing the survival and shedding of STEC from cattle guts. Let's look at the different targets in more detail.

External environment:

Management factors are important for biosecurity and animal health and may help reduce the burden of STEC, however, they will not eliminate *E. coli* O157:H7 from the environment.

- **Season:** STEC burden is higher in **warmer summer months** [7, 8], likely because conditions are more favorable for STEC replication in the environment. Season is one of the most reliable predictors for STEC shedding across studies and efforts to minimize STEC shedding from cattle should be intensified during the warmer months.
- **Stress:** Weaning and transport have been associated with increased STEC shedding [9, 10] and there is evidence that the stress hormone norepinephrine stimulates *E. coli* O157 growth [11]. Low-stress handling may be helpful in reducing STEC shedding.
- **Manure:** Super-shedders are thought to be the biggest contributors to pen contamination and transmission. 20% of *E. coli* O157:H7 shedding cattle are responsible for 80% of infections in cattle [12]. Unfortunately, we still don't have the means to easily identify and mitigate super-shedders. However, reducing manure as a source of transmission through pen cleaning and proper stocking density may help reduce overall STEC shedding.
- **Water troughs:** *E. coli* O157:H7 is commonly found in pen water troughs and survives in this environment, especially at colder water temperatures [13]. Addition of disinfectants such as chlorine at 2 to 5 ppm (2 to 5 ml chlorine per 1000 L of water), 0.1% caprylic acid or trans cinnamaldehyde have been effective in reducing or inactivating *E. coli* O157:H7, but palatability and water intake by cattle may be impaired [14, 15]. In addition, organic matter such as algae and feces inactivate disinfectants quickly. Overall, water trough management,

while important for cattle health and welfare, has not been identified as an efficient means to reduce STEC shedding.

- **Other species:** Rodents, insects, birds (starlings, cowbirds, egrets, wild geese), pigs, sheep and deer have all been shown to carry STEC or to increase the risk of cattle shedding STEC if found in cattle proximity [16-21]. While reducing contact of these species with cattle can have many benefits, the direct effect on STEC shedding is probably limited [22].

Internal environment:

Feeds that are associated with **increased** STEC shedding:

- **Distillers grains:** multiple studies have shown increased *E. coli* O157 shedding with feeding brewer's grains [23], dried distiller's grains [24] or wet distiller's grains [25]. The suggested mechanism is that distiller's grains are highly rumen digestible, leading to less starch passing to the hindgut and resulting in a higher fecal pH, which may be more hospitable to *E. coli* O157 [26]. However, the relationship between hindgut starch fermentation, pH and STEC survival is more complex than this and study results with other feed stuffs show different relationships [27].
- **Fasting:** fasting leads to a decrease in the amount of volatile fatty acids in the ruminant digestive tract and has been associated with an increase in STEC shedding [22].

Feeds that are associated with **decreased** STEC shedding:

- **Orange peel:** when fed at 10% dry matter to sheep in a mixture with dried orange pellets, fresh orange peel reduced *E. coli* O157:H7 in the intestinal tract of experimentally infected sheep [28].
- **Cottonseed:** Feeding whole cottonseed was associated with decreased shedding of *E. coli* O157:H7 in dairy calves [29].
- **Tasco:** a brown seaweed (*Ascophyllum nodosum*) feed additive marketed to improve intestinal health has been shown to reduce *E. coli* O157:H7 in feces by 11% [30]. This product is available in the US through Tasco's distributor Nutrablend.
- **Essential oils:** citrus oils have shown antimicrobial activity against *E. coli* O157:H7 in vitro, but controlled studies in live animals are still lacking [27].

Probiotics

Probiotics are beneficial bacteria such as *Lactobacillus acidophilus* or *Propionibacterium freudenreichii*. These bacteria work by crowding out harmful bacteria and/or promoting host immunity. Studies have shown that products containing certain probiotics can successfully reduce *E. coli* O157:H7 shedding in cattle. Bovamine Defend® is a product that has performed well in multiple studies at reducing the risk of shedding [31, 32].

Vaccines

There is currently one vaccine conditionally licensed in the U.S. named Escherichia Coli Bacterial Extract vaccine with SRP® that is targeted against *E. coli* O157. It is marketed by Zoetis and available through veterinarians. It is labelled for vaccination of healthy cattle 5 months or older. Three doses are recommended, however the duration of immunity is unknown and there is a 60 day slaughter withdrawal period. The SRP in the vaccine's name stands for Siderophore Receptors and Porins, which are transport proteins in the *E. coli* cell surface that are necessary for iron transport into the bacterial cell. The vaccine elicits an antibody response against bacterial SRP proteins. In a field trial, cattle that received three doses of vaccine were 84.7% less likely to shed STEC, and those vaccinated that did shed had a 98% reduction in fecal bacterial concentration compared to a placebo group [33]. In a second study, where only 2 doses were given, overall shedding was reduced by 53% and the number of high shedders (shedding more than 10,000 CFU/g feces) was reduced by 77% [34]. Unlike in the first study, the second study saw a small reduction in average daily gain by 2.7% in vaccinated animals, which was contributed to the additional processing when giving the booster injection compared to control animals. In the first study all animals received three injections, either vaccine or placebo.

Vaccines for *E. coli* O157:H7 are not intended to improve the well-being or performance of cattle as *E. coli* O157:H7 is considered a commensal in cattle, not causing disease. So far, the cattle industry has shown little interest for the vaccine, because there is no perceived marketable benefit. It is also important to understand that while they seem to reduce shedding, *E. coli* O157:H7 vaccines are unlikely to eliminate all shedding of STEC from cattle.

Another point to ponder is that any of the prevention measures outlined may become futile from a meat safety standpoint, if treated cattle are mixed with untreated cattle during transport to slaughter through the spread of contaminated feces on hides [6].

Future possibilities

The addition of sodium chlorate to cattle feed or drinking water has shown promising results in *E. coli* O157:H7 reduction but its use in food producing animals is not approved by the FDA [35]. Bacteriophages are viruses that target bacteria and are already in use for reduction of *E. coli* on cattle hides at the slaughter plant. Studies in live animals have shown that phages can reduce *E. coli* O157:H7 shedding in ruminants but large-scale therapy is thought to be difficult to implement [36, 37]. Other bacterial targets for vaccines are being investigated.

Summary

E. coli O157:H7 is shed by many healthy cattle and does not cause disease in cattle. However, it is a pathogen for people and can lead to serious disease and even death if consumed. No measure will be able to completely eliminate shedding from cattle, but reduction is possible through management, nutrition or vaccination. The decision to apply any of the measures highlighted should be based on feasibility and a cost/benefit analysis in discussion with a nutritionist and/or veterinarian.

References

1. Rangel, J.M., et al., *Epidemiology of Escherichia coli O157:H7 outbreaks, United States, 1982-2002*. Emerg Infect Dis, 2005. **11**(4): p. 603-9.
2. *Outbreak of E. coli infections linked to romaine lettuce*. Am J Transplant, 2019. **19**(1): p. 291-293.
3. Brichta-Harhay, D.M., et al., *Salmonella and Escherichia coli O157:H7 contamination on hides and carcasses of cull cattle presented for slaughter in the United States: an evaluation of prevalence and bacterial loads by immunomagnetic separation and direct plating methods*. Appl Environ Microbiol, 2008. **74**(20): p. 6289-97.
4. Administration, F.a.D. *Environmental Assessment of Factors Potentially Contributing to the Contamination of Romaine Lettuce Implicated in a Multi-State Oubreak of E. coli O157:H7*. 2018 1/7/2018]; Available from: <https://www.fda.gov/Food/RecallsOutbreaksEmergencies/Outbreaks/ucm624546.htm>.
5. Savageau, M.A., *Escherichia-Coli Habitats, Cell-Types, and Molecular Mechanisms of Gene-Control*. American Naturalist, 1983. **122**(6): p. 732-744.
6. Smith, D.R., *Vaccination of Cattle against Escherichia coli O157:H7*. Microbiol Spectr, 2014. **2**(6).
7. Van Donkersgoed, J., T. Graham, and V. Gannon, *The prevalence of verotoxin, Escherichia coli O157:H7, and Salmonella in the feces and rumen of cattle at processing*. Can Vet J, 1999. **42**: p. 714-720.
8. Barkocy-Gallagher, G.A., et al., *Seasonal prevalence of Shiga toxin-producing Escherichia coli, including O157:H7 and non-O157 serotypes, and Salmonella in commercial beef processing plants*. J Food Prot, 2003. **66**(11): p. 1978-86.
9. Herriott, D.E., et al., *Association of herd management factors with colonization of dairy cattle by Shiga toxin-positive Escherichia coli O157*. J Food Prot, 1998. **61**(7): p. 802-7.
10. Bach, S.J., et al., *Long-haul transport and lack of preconditioning increases fecal shedding of Escherichia coli and Escherichia coli O157:H7 by calves*. J Food Prot, 2004. **67**(4): p. 672-8.
11. Bansal, T., et al., *Differential effects of epinephrine, norepinephrine, and indole on Escherichia coli O157:H7 chemotaxis, colonization, and gene expression*. Infect Immun, 2007. **75**(9): p. 4597-607.
12. Matthews, L., et al., *Super-shedding cattle and the transmission dynamics of Escherichia coli O157*. Epidemiol Infect, 2006. **134**(1): p. 131-42.
13. Rice, E.W. and C.H. Johnson, *Short communication: survival of Escherichia coli O157:H7 in dairy cattle drinking water*. J Dairy Sci, 2000. **83**(9): p. 2021-3.
14. Charles, A.S., et al., *Reduction of Escherichia coli O157:H7 in cattle drinking-water by trans-cinnamaldehyde*. Foodborne Pathog Dis, 2008. **5**(6): p. 763-71.
15. Amalaradjou, M.A., et al., *Inactivation of escherichia coli O157:H7 in cattle drinking water by sodium caprylate*. J Food Prot, 2006. **69**(9): p. 2248-52.
16. Cernicchiaro, N., et al., *Association of wild bird density and farm management factors with the prevalence of E. coli O157 in dairy herds in Ohio (2007-2009)*. Zoonoses Public Health, 2012. **59**(5): p. 320-9.
17. Stacey, K.F., et al., *Assessing the effect of interventions on the risk of cattle and sheep carrying Escherichia coli O157:H7 to the abattoir using a stochastic model*. Prev Vet Med, 2007. **79**(1): p. 32-45.

18. Ahmad, A., T.G. Nagaraja, and L. Zurek, *Transmission of Escherichia coli O157:H7 to cattle by house flies*. *Prev Vet Med*, 2007. **80**(1): p. 74-81.
19. French, E., A. Rodriguez-Palacios, and J.T. LeJeune, *Enteric bacterial pathogens with zoonotic potential isolated from farm-raised deer*. *Foodborne Pathog Dis*, 2010. **7**(9): p. 1031-7.
20. Rice, D.H., D.D. Hancock, and T.E. Besser, *Faecal culture of wild animals for Escherichia coli O157:H7*. *Vet Rec*, 2003. **152**(3): p. 82-3.
21. Gunn, G.J., et al., *An investigation of factors associated with the prevalence of verocytotoxin producing Escherichia coli O157 shedding in Scottish beef cattle*. *Vet J*, 2007. **174**(3): p. 554-64.
22. Callaway, T.R., et al., *Shiga Toxin-Producing Escherichia coli (STEC) Ecology in Cattle and Management Based Options for Reducing Fecal Shedding*. *Agric. Food Anal. Bacteriol.*, 2013. **3**(1): p. 39-69.
23. Dewell, G.A., et al., *Prevalence of and risk factors for Escherichia coli O157 in market-ready beef cattle from 12 U.S. feedlots*. *Foodborne Pathog Dis*, 2005. **2**(1): p. 70-6.
24. Jacob, M.E., et al., *Feeding supplemental dried distiller's grains increases faecal shedding of Escherichia coli O157 in experimentally inoculated calves*. *Zoonoses Public Health*, 2008. **55**(3): p. 125-32.
25. Wells, J.E., et al., *Prevalence and level of Escherichia coli O157:H7 in feces and on hides of feedlot steers fed diets with or without wet distillers grains with solubles*. *J Food Prot*, 2009. **72**(8): p. 1624-33.
26. Berry, E.D. and J.E. Wells, *Escherichia coli O157:H7: recent advances in research on occurrence, transmission, and control in cattle and the production environment*. *Adv Food Nutr Res*, 2010. **60**: p. 67-117.
27. Jacob, M.E., T.R. Callaway, and T.G. Nagaraja, *Dietary interactions and interventions affecting Escherichia coli O157 colonization and shedding in cattle*. *Foodborne Pathog Dis*, 2009. **6**(7): p. 785-92.
28. Callaway, T.R., et al., *Escherichia coli O157:H7 populations in ruminants can be reduced by orange peel product feeding*. *J Food Prot*, 2011. **74**(11): p. 1917-21.
29. Garber, L.P., et al., *Risk factors for fecal shedding of Escherichia coli O157:H7 in dairy calves*. *J Am Vet Med Assoc*, 1995. **207**(1): p. 46-9.
30. Braden, K.W., et al., *Ascophyllum nodosum supplementation: a preharvest intervention for reducing Escherichia coli O157:H7 and Salmonella spp. in feedlot steers*. *J Food Prot*, 2004. **67**(9): p. 1824-8.
31. Stephens, T.P., et al., *Reduction of Escherichia coli O157 and Salmonella in feces and on hides of feedlot cattle using various doses of a direct-fed microbial*. *J Food Prot*, 2007. **70**(10): p. 2386-91.
32. Younts-Dahl, S.M., et al., *Dietary supplementation with Lactobacillus- and Propionibacterium-based direct-fed microbials and prevalence of Escherichia coli O157 in beef feedlot cattle and on hides at harvest*. *J Food Prot*, 2004. **67**(5): p. 889-93.
33. Thomson, D.U., et al., *Use of a siderophore receptor and porin proteins-based vaccine to control the burden of Escherichia coli O157:H7 in feedlot cattle*. *Foodborne Pathog Dis*, 2009. **6**(7): p. 871-7.
34. Cull, C.A., et al., *Efficacy of a vaccine and a direct-fed microbial against fecal shedding of Escherichia coli O157:H7 in a randomized pen-level field trial of commercial feedlot cattle*. *Vaccine*, 2012. **30**(43): p. 6210-5.
35. Callaway, T.R., et al., *Sodium chlorate supplementation reduces E. coli O157:H7 populations in cattle*. *J Anim Sci*, 2002. **80**(6): p. 1683-9.
36. Callaway, T.R., et al., *Bacteriophage isolated from feedlot cattle can reduce Escherichia coli O157:H7 populations in ruminant gastrointestinal tracts*. *Foodborne Pathog Dis*, 2008. **5**(2): p. 183-91.
37. Sheng, H., et al., *Application of bacteriophages to control intestinal Escherichia coli O157:H7 levels in ruminants*. *Appl Environ Microbiol*, 2006. **72**(8): p. 5359-66.