Pre-Harvest Food Safety Interventions on Cattle Farms

Thomas E. Besser*, Dale D. Hancock, Daniel H. Rice, Clive C. Gay and John M. Gay

Introduction

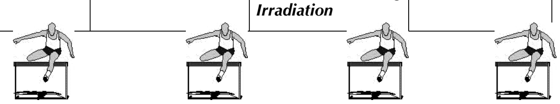
The impetus for considering pre-harvest efforts for shiga toxigenic *E. coli* O157 (O157) has been the growing recognition that the risk of foodborne disease associated with O157 cannot be eliminated at processing, retailing, or consumer levels. This has led to the multiple hurdles model in which some reduction is made at each of several levels (Figure 1). Since reductions are multiplicative, the overall effect is to greatly reduce the risk of human infection.

The primary reason to suspect that risk reduction is possible at the pre-harvest (farm) level is the fact that cattle entering the slaughter plant are the main source of O157 for contamination of meat. In a survey of feedlot cattle in holding pens at a slaughter plant, about 2% were found to excrete O157. Among a small number of post-killed cattle at 8 slaughter plants about 5% were fecal positive and additional animals had evidence of hide contamination. For a slaughter plant receiving and processing 2000 head per day (for example), dozens of O157 colonized or contaminated cattle would be received per day. Any significant reduction in the prevalence of O157 in incoming cattle would be expected to directly reduce risk of contamination at subsequent processing levels.

FIGURE 1.

Multiple Hurdles for Control of Disease Associated With Shigatoxin-Producing *E. Coli* O157

Consumer	Retail	Slaughter and Processing	Production
Temperature Control refrigeration cooking post-cook holding **Cross Contamination** surfaces utensils hands containers	**Temperature Control** **Holding time** **Re-grinding**	**Carcass/Meat Contamination** from hide from gutting from handling from equipment **Carcass Cleaning** steam wash **Temperature Control** initial chill boning transit and holding ***Irradiation***	**Hide soiling** **Susceptibility** time off-feed competitive inhibition **Feed Exposure** contamination replication **Water Exposure** contamination survival replication



The widespread adoption of the multiple hurdles approach has been due to the recognition that absolute control is not possible at any level.

T. E. Besser
Dept. Vet. Microbiology & Pathology
P.O. Box 647040
Pullman WA 99164-7040
tbesser@vetmed.wsu.edu
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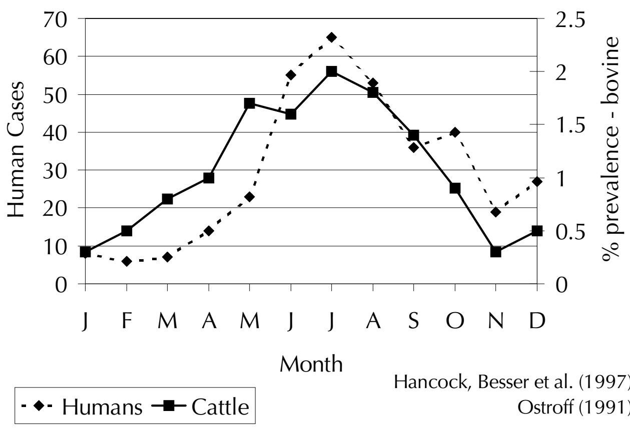
On Farm Epidemiology of O157

Identification of effective control strategies at the farm level requires that an understanding the ecology of O157. Important features of O157 epidemiology include:

1. O157 exists at least intermittently on a majority of cattle farms (Garber 1994, Hancock 1994, Hancock 1997a, Hancock 1997d, Hancock 1997e).
2. It is distributed across the U.S. in both dairy and beef cattle (Garber 1994, Hancock 1997e).
3. The percent of cattle infected with O157 is typically < 5% (Besser 1997, Garber 1994, Hancock 1994, Hancock 1997a, Hancock 1997d, Hancock 1997, Sanderson 1995).
4. O157 has been detected at a similar, or slightly higher, prevalence among cattle being held at slaughter plants and on the external surface of the hides of recently slaughtered animals (Hancock 1999).
5. O157 has been found in species other than cattle, including deer, sheep, dogs, horse, flies, and birds (Hancock 1998, Keene 1997, McCluskey 1997, Rice 1995a, Rice 1995b). However, a long-term reservoir species (if one exists) has not been identified.
6. Colonization of cattle with O157 is typically of short duration (1-2 months), and long term carriers have not been found (Besser 1997, Besser 1999).
7. O157 is not associated with any recognizable disease in cattle, but instead appears to behave as transient *E. coli* "normal flora" (Besser 1997, Besser 1999, Hancock 1997b).
8. At least some cattle can be colonized by low doses of O157 (< 250 cfu), and these animals amplify the infection and transmit O157 to other cattle (Besser, 1999).
9. Growing cattle 3-18 months of age have a higher prevalence of O157 than either younger (suckling) calves or adult cattle, (Hancock 1994, Hancock 1997a, Garber 1995) which is likely reflective of a less stable *E. coli* flora among younger animals (Hancock 1997b).

10. O157 prevalence in a herd is not associated with manure application to grazing land. (Hancock 1997d). Tentative associations with other management factors have been observed but have not yet been tested in targeted studies (Dargatz 1997, Garber 1995, Hancock 1994, Hancock 1997d, Herriott 1997).
11. The typical pattern of O157 shedding in a herd followed over time is one of epidemics of shedding interspersed with longer periods with rare or no shedding animals (Hancock 1997a, Hancock 1997d). These epidemics occur mainly during warm weather, suggesting that environmental proliferation may play an important role in the epidemiology of this agent (Figure 2, Hancock 1994, Hancock 1997a, Keene 1999).
12. O157 can multiply prolifically in cattle feeds when moisture is added, which commonly occurs in mixed rations (Lynn 1998).
13. O157 has been found in water troughs on numerous farms. O157 persists at least 4 months in water trough sediments and may even multiply in this environment, suggesting that water troughs could be a long-term reservoir which maintains O157 in herds during periods of low infection prevalence (Hancock 1998, Hancock 1999).
14. Considerable strain diversity among O157 isolates can be detected, between and even within some herds. Specific strains of O157 can persist on particular farms for at least 2 years (Rice 1999).
15. Regional transmission of O157 appears to occur, since indistinguishable strains have been found in herds > 500 km apart. Isolates from non-bovine species are closely related or identical to bovine isolates from the same premises (Rice 1999).

FIGURE 2.



Hancock, Besser et al. (1997)
Ostroff (1991)

Fecal E. coli O157 shedding increases markedly in warm months as does the incidence of human disease associated with this agent.

FIGURE 3.

Levels of Possible Farm-Level Control

- Eradication
- Establishment of biosecurity in herds
- Ecological measures to reduce contamination level
  - Animal feed safety
  - Animal water safety
  - Factors affecting host susceptibility

Although eradication or establishment of biosecurity for individual may be the ultimate form of control of an infectious agent, they are not feasible for O157, which is a ubiquitous agent with multiple host species. Although ecological measures will not eradicate the agent, they can feasibly greatly reduce the prevalence of infected cattle entering slaughter plants.

FIGURE 4.

450 kg feedlot steer at 32 C

Intakes
15 kg feed (70% DM)
78 liters of water

Feed *E. Coli* concentration/g (as fed)	**Water *E. coli* concentration /ml**				
	4	**16**	**64**	**256**	**1,024**
10	462,000	1,398,000	5,142,000	20,118,000	80,022,000
100	1,812,000	2,748,000	6,492,000	21,468,000	81,372,000
1,000	15,312,000	16,248,000	619,992,000	34,968,000	94,872,000
10,000	150,312,000	151,248,000	154,992,000	169,968,000	229,872,000
100,000	1,500,312,000	1,501,248,000	1,504,992,000	1,519,968,000	1,579,872,000

Total daily intakes of generic E. coli for a finishing steer consuming water and feed of different E. coli concentrations. The range of levels shown for feed and water are within the range of farm-to-farm variation that has been observed in cattle operations. Although the habits of cattle (grooming, etc) dictate a certain E.coli intake, it appears that most of the farm to farm variation in intakes is due to feed and water contamination levels. The concentrations in both feed and water increase in some herds seasonally which hypothetically accounts for the sharp increases in prevalence during warm months.

16. O157 is not subject to eradication, either from whole birds, deer, and other wildlife (Figure 3). This feature is shared with most other foodborne disease agents including *Campylobacter, Salmonella, Listeria*, and others. Although recognition of the impossibility of eradicating these agents has led to pessimism about control in general, several ecological measures promise great reduction in the prevalence of O157 (and perhaps other agents) among cattle presented at slaughter.

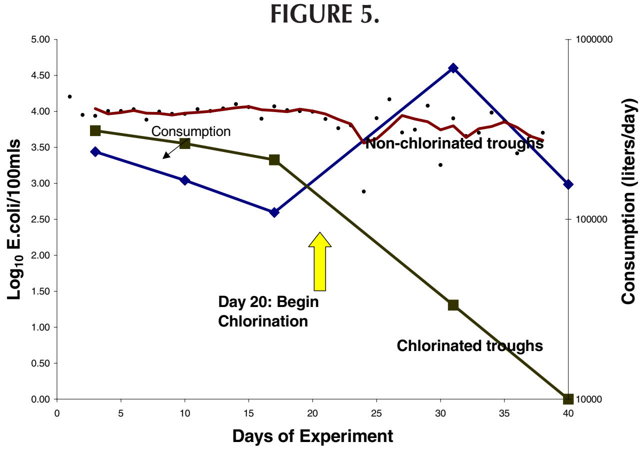
Possible Ecologic Approaches to Control of O157

One promising area for ecologic control of O157 is water management (Figure 4). Water can maintain O157 for months, and contaminated water troughs are frequently implicated as sources of O157 infection for cattle. Reductions in total enteric bacterial intake in water are expected to reduce the exposure and infection of cattle by O157 and other pathogens. Can the numbers of enteric bacteria in water troughs be significantly reduced? Simple cleaning does not accomplish this since sediments that accumulate within 24 hours support robust bacterial growth, particularly in warm months. Chemical treatments of troughs, especially chlorination, offer more promise. While it is unlikely that chlorination will eliminate bacterial contamination and survival in sediments, it is likely that chlorination can significantly reduce bacterial counts in the water column. However, for this to be accomplished, it is expected that troughs must be designed that promote high volume turnover, leading to better maintenance of free chlorine levels over time. For example, our preliminary studies on chlorination of water for feedlot cattle show promising reductions in total *E. coli* counts, without significant effects on water consumption (Figure 5).

A second ecologic approach to reducing O157 infections in cattle is control of contaminated feeds. Total mixed rations on farms frequently contain very high *E. coli* concentrations of >10,000 cfu/g, mostly due to proliferation of *E. coli* during and after preparation. In mixed rations with a silage component, naturally occurring propionic acid is the best predictor of failure of the ration to support proliferation of contaminating enteric bacteria, including *E. coli* and *Salmonella* sp. Furthermore, addition of low concentrations of propionic acid or propionate salts equally fail to support proliferation of these agents. Propionate, or similarly effective chemicals added to mixed feeds may be an effective method to prevent replication of enteric bacteria in feeds in warm months. Although some contamination of feed is unavoidable from handling equipment, flies, birds, etc., the natural variation in coliform contamination of feeds among farms indicates that the greatest determinant of contaminant dose is whether or not the ration supports bacterial growth.

A third ecological approach of O157 is increasing the resistance of cattle to colonization. One possible means of accomplishing this is strategic colonization (via inoculation) with bacteria that compete with O157 for nutrients or binding sites or otherwise inhibit its ability to colonize, or competitive exclusion (CE). The effectiveness of CE has been well documented for salmonella in broiler chicks and several lines of evidence suggest it might be effective for O157 in cattle. As with salmonella in poultry, the GI flora of adults appears to be relatively inhibitory to O157 colonization. The sharply higher prevalence of O157 in recently shipped feedlot cattle is probably due to disturbances of the normal gastrointestinal flora which could potentially be impacted with CE. Research on CE targeting O157 is underway in the lab of Mike Doyle at the University of Georgia.

FIGURE 5.



Chlorination of source well water at 1 to 2 ppm resulted in detectable free chlorine in the trough water column for at least 10 days post cleaning, and significantly reduced total E. coli counts without significantly reducing water consumption by feedlot cattle.

Summary

Since O157 emerged as an important food-borne infection, control at the pre-harvest (on-farm) level has been theoretically possible but no specific proven procedures have been available for implementation. However, our understanding of this infection in food-producing animals has rapidly expanded. Our understanding of the ecology and epidemiology of O157 infection in cattle has now reached the point where several logical and practical methods to reduce cattle infections have been identified and are under active investigation. In the near future, we expect these methods will be tested for effects on O157 infections, and for the first time proven, on-farm (pre-harvest) control of O157 infections will be available to supplement control measures already in place at the subsequent stages of slaughter, processing, and food preparation.

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