

# **PRE-HARVEST MANAGEMENT CONTROLS AND INTERVENTION OPTIONS FOR REDUCING *ESCHERICHIA COLI* O157:H7 SHEDDING IN CATTLE**

## **May 2010**

### Introduction

This guidance document provides beef slaughter establishments with an informational resource on pre-harvest management controls for reducing *E. coli* O157:H7 shedding in beef cattle. Non-intact beef products or intact beef products that are to be further processed into non-intact beef products prior to distribution for consumption are adulterated if found to be contaminated with *E. coli* O157:H7 (64 FR 2904). Establishments are required to conduct a hazard analysis that includes food safety hazards that can occur before, during, or after entry into the establishment (9 CFR 417.2). Fecal shedding in cattle is a hazard that occurs at pre-harvest, before entry into the establishment. Establishments may address this hazard by incorporating purchase specifications or other programs or agreements as part of their HACCP plans or prerequisite programs to require that their suppliers implement certain pre-harvest management controls.

The Food Safety and Inspection Service (FSIS) recommends that slaughter establishments receive their cattle from beef producers that implement one or more documented pre-harvest management practices to reduce fecal shedding. FSIS encourages pre-harvest interventions as the first control steps in an integrated beef products safety system. Pre-harvest interventions, adequate sanitary dressing procedures at slaughter, and adequate sanitary conditions during further processing are a part of an integrated approach to reduce the public health impact of *E. coli* O157:H7. Thus, beef producers, slaughterers, and processors should work together to control *E. coli* O157:H7 to reduce its presence in beef products.

This guidance document describes several pre-harvest interventions and management practices that are the subject of research, the state of the findings about these practices, and a link to additional references. Research on pre-harvest interventions is ongoing and developing. Pre-harvest interventions that eliminate fecal shedding have yet to be discovered; however, current research suggests that at least two pre-harvest interventions, certain probiotics, and perhaps vaccines have the potential to be effective in reducing fecal shedding in cattle. FSIS encourages slaughter establishments to share this information with their suppliers and to use it in designing their food safety systems.

This guidance document follows the procedures for guidance documents in the Office of Management and Budget's (OMB) "Final Bulletin for Agency Good Guidance Practices." More information on OMB's policies and procedures can be found on the FSIS webpage:

[www.fsis.usda.gov/Significant\\_Guidance/index.asp](http://www.fsis.usda.gov/Significant_Guidance/index.asp)

This guidance document represents FSIS's current thinking on this topic. FSIS encourages beef slaughter establishments to begin following this guidance. This document includes recommendations rather than regulatory requirements.

FSIS requests all persons interested to submit comments regarding any aspect of this document, including but not limited to: content, readability, applicability, and accessibility. The comment period will be 60 days.

Comments may be submitted by either of the following methods:

Federal eRulemaking Portal: This Web site provides the ability to type short comments directly into the comment field on this Web page or attach a file for lengthier comments. Go to <http://www.regulations.gov>. Follow the online instructions at that site for submitting comments.

Mail, including floppy disks or CD-ROMs, and hand- or courier-delivered items: Send to Docket Clerk, U.S. Department of Agriculture (USDA), FSIS, Room 2-2127, George Washington Carver Center, 5601 Sunnyside Avenue, Mailstop 5474, Beltsville MD 20705-5474.

Instructions: All items submitted by mail or electronic mail must include the Agency name and docket number FSIS-2009-0034. Comments received in response to this docket will be made available for public inspection and posted without change, including any personal information to <http://www.regulations.gov>.

### Background Information on *E. coli* O157:H7 Shedding in Cattle

*E. coli* O157:H7 is a food safety hazard well documented in scientific research. Attachment 1, "What is *E. coli* O157:H7?", and Attachment 2, "Ecological and Epidemiological Characteristics of *E. coli* O157:H7", provides general information regarding the pathogen. Attachment 3 is a quick reference table that summarizes the pre-harvest management options and interventions presented in this guidance.

### Pre-Harvest Cattle Management Controls

The beef industry is investigating production practices that reduce food safety risks. To date, industry has invested heavily in processing interventions to address *E. coli* O157:H7 in raw beef products. Despite these measures, *E. coli* O157:H7 remains a food safety hazard in our food supply. Pre-harvest cattle management controls and interventions are emerging as an option that offers great opportunity to improve food safety.

Consensus within the beef industry is that beef producers should follow basic recommended principles of cattle management. The following are the basic recommended principles of cattle management.

1. Clean water;
2. Clean feed;
3. Clean environment that is appropriately drained;
4. Separate housing of calves and heifer or reduced animal density; and
5. Biosecurity—wildlife exclusion to the extent possible.

Current research has not shown a reduction *E. coli* O157:H7 shedding in cattle when these basic principles are used. Nevertheless, FSIS supports the principles because of their foundation in animal health and welfare. They provide a foundation for the processing interventions and sanitary dressing procedures used to control *E. coli* O157:H7 contamination in raw beef.

Additional references:

- Beef Industry Food Safety Council – BIFSCO *E. coli* O157 Solutions: The Pre-Harvest Commitment.
- Stevens, M.P., P.M. Van Dieme, F. Dziva, P.W. Jones, and T.S. Wallis. 2002. Options for the control of enterohaemorrhagic *Escherichia coli* in ruminants. Microbiology 148 pages.
- Oliver, S.P., Patel, D.A., T.R. Callaway,, M.E. Torrence. 2009. ASAS Centennial Paper: Developments and future outlook for preharvest food safety. J. Anim Sci. 87:419-437.
- Loneragan, G.H., M.M. Brashears. 2005. Preharvest interventions to reduce carriage of *E. coli* O157 by harvest-ready feedlot cattle. Meat Science. 71:72-78.

## Pre-Harvest Management Controls and Interventions to Reduce *E. coli* O157:H7 Shedding in Cattle

This section summarizes ongoing research regarding pre-harvest interventions and management practices. The preharvest management practices and interventions are divided into the following general areas: (1) cattle water and feed, (2) live animal treatments, and (3) management practices and transportation.

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### Cattle Water and Feed Management

**Key Point:** Providing cattle with treated drinking water sources is one way to reduce herd transmission; however, it does not directly reduce *E. coli* O157:H7 shedding in cattle.

#### (1) Cattle Drinking Water Treatments:

Applications: Research suggests that there is a correlation between cattle that drink contaminated water and *E. coli* O157:H7 shedding. Researchers are studying the application of chlorination, electrolyzed water, and ozonation as water treatments to improve and maintain drinking water quality.

Chlorine is a FDA approved and commercially available water treatment used to disinfect cattle drinking water and to reduce the transmission of pathogens including *E. coli* O157:H7. Beef producers that use chlorine must maintain the required chlorine levels throughout the day in order to disinfect trough water effectively. Electrolyzed water and ozonation are also water treatment methods; however, specialized equipment is required to apply these interventions to drinking water sources. In addition, researchers have not tested electrolyzed water under field conditions.

Findings: Adding chlorine to water at 2-5 PPM significantly reduces total *E. coli* concentrations. However, the effectiveness of the chlorine is diminished if organic material, such as manure, is present in the water. Under field conditions, treating livestock drinking water with chlorine has been shown to have a negligible effect on the prevalence of *E. coli* O157:H7. Chlorine water treatment may be more practical to implement than electrolyzed water and ozonation; however its effect on *E. coli* O157:H7 shedding is inconclusive.

#### Additional references:

- LeJeune, J.T., T.E. Besser, D.H. Rice, J.L. Berg, R.P. Stilborn, and D.D. Hancock. 2004. Longitudinal study of fecal shedding of *Escherichia coli* O157:H7 in feedlot cattle: Predominance and persistence of specific clonal types despite massive cattle population turn over. *Appl. Environ. Microbiol.* 70:377–384.

- Besser, T.E., J.T. LeJeune, D.H. Rice, J. Berg, R.P. Stilborn, K. Kaya, W. Bae, and D.D. Hancock. 2005. Increasing prevalence of *Campylobacter jejuni* in feedlot cattle through the feeding period. *Appl. Environ. Microbiol.* 71:5752–5758.
  - Zhao, T., S. Tkalcic, M.P. Doyle, B.G. Harmon, C.A. Brown, and P. Zhao. 2003. Pathogenicity of enterohemorrhagic *Escherichia coli* in neonatal calves and evaluation of fecal shedding by treatment with probiotic *Escherichia coli*. *J. Food Prot.* 66:924–930.
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## (2) Cattle Feed Types and Feeding Strategies

**Key Point:** Changes in diet can alter the *E. coli* O157:H7 shedding in cattle, but the observed change is inconsistent.

### A. Feed Types

Application: Research indicates that the type of feed, fasting, and feed additives can affect *E. coli* O157 shedding in cattle. Researchers have studied the effects of feeding hay, grain, distiller grains, and forage on *E. coli* O157:H7 shedding in cattle.

Findings: In general, research supports that cattle on grain-based diets shed higher levels of generic *E. coli* in their feces than cattle on a high-forage diet. Studies suggest that varying the forage-to-grain ratio in cattle rations can have an effect on *E. coli* population in cattle feces. A decrease in the *E. coli* O157 shedding has been observed when cattle and sheep are fed poor quality forage or fasted. Other researchers have observed inconsistent shedding or an increase in *E. coli* O157 shedding when the diet is switched from a high grain ration to a high quality hay or low quality forage. Some factors intrinsic to forage may explain some of the observations and inconsistencies found between forage and grain-based diets. Most research suggests that distiller's grain may increase *E. coli* O157:H7 shedding in cattle. Researchers studied wet and dried distiller's grain with variable results. The fiber component of hay may scrape the gut wall, physically removing the organism and contributing to reduced colonization and shedding.

#### Additional references:

- Diez-Gonzalez, F., T.R. Callaway, M.G. Kizoulis, and J.B. Russell. 1998. Grain Feeding and the Dissemination of Acid-Resistant *Escherichia coli* from Cattle. *Science* 281:1666-1668.

- Allison, M.J., I.M. Robinson, R.W. Dougherty, and J.A. Bucklin. 1975. Grain overload in cattle and sheep: changes in microbial populations in the cecum and rumen. *Am. J. Vet. Res.* 36:181–185.
- Jordan, D., and S.A. McEwen. 1998. Effect of duration of fasting and a short-term high-roughage ration on the concentration of *Escherichia coli* biotype 1 in cattle feces. *J. Food Prot.* 61:531–534.
- Scott, T., C. Wilson, D. Bailey, T. Klopfenstein, T. Milton, R. Moxley, D. Smith, J. Gray, and L. Hungerford. 2000. Influence of diet on total and acid resistant *E. coli* and colonic pH. *Nebraska Beef Rep.* 39–41.
- Buchko, S.J., R.A. Holley, W.O. Olson, V.P.J. Gannon, D.M. Veira. 2000. The effect of fasting and diet on fecal shedding of *Escherichia coli* O157:H7 by cattle. *Can. J. Anim. Sci.* 80:741–744.
- Stanton, T.L., and D. Schutz. 2000. Effect of switching from high grain to hay five days prior to slaughter on finishing cattle performance. Colorado State Univ. Research Report. Ft. Collins, CO.
- Keen, J.E., G.A. Uhlich, R.O. Elder. 1999. Effects of hay and grain-based diets on fecal shedding in naturally-acquired enterohemorrhagic *E. coli* (EHEC) O157 in beef feedlot cattle. 80th. Conference Research Workers in Animal Diseases, Nov. 7–9, Chicago, IL.
- Kudva, I.T., P.G. Hatfield, C.J. Hovde. 1995. Effect of diet on the shedding of *Escherichia coli* O157:H7 shedding in a sheep model. *Appl. Environ. Microbiol.* 61:1363–1370.
- Grauke, L.J., S.A. Wynia, H.Q. Sheng, J.W. Yoon, C.J. Williams, C.W. Hunt, C.J. Hovde. 2003. Acid resistance of *Escherichia coli* O157:H7 from the gastrointestinal tract of cattle fed hay or grain. *Vet Microbiol.* 95(3):211-25.
- Gregory, N.G., L.H. Jacobson, T.A. Nagle, R.W. Muirhead, G.J. Lerouz Mirinz. 2000. Effect of preslaughter feeding system on weight loss, gut bacteria, and the physico-chemical properties of digesta in cattle. *New Zealand Journal of Agricultural Research.* 43:351-361.
- Low, J.C., I.J. McKendrick, C. McKechnie, D.R. Fenlon, S.W. Naylor, C. Currie, D.G.E. Smith, L. Allison D.L. Gally. 2005. Rectal carriage of enterohemorrhagic *Escherichia coli* O157 in slaughtered cattle. *Appl. Environ. Microbiol.* 71:93-97

- Naylor, S.W., J.C. Low, T.E. Besser, A. Mahajan, G.J. Gunn, M.C. Pearce, I.J. McKendrick, D.G.E. Smith, D.L. Gally. 2003. Lymphoid follicle-dense mucosa at the terminal rectum is the principal site of colonization of enterohaemorrhagic *Escherichia coli* O157:H7 in the bovine host. *Infect. Immun.* 71:1505-1512.
  - Callaway T.R., M.A. Carr, T.S. Edrington, R.C. Anderson, D.J. Nisbet. 2008. Diet, *E. coli* O157:H7 and cattle: A review after 10 years. *Issues Mol. Biol* 11:67-80.
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## **B. Feeding Hay When Finishing Cattle**

Application: Most US beef producers feed cattle a grain finishing diet.

Findings: Research suggests that feeding cattle hay in place of grain decreases the risk of food borne illness from *E. coli* O157:H7. A 2000 study showed that when cattle are switched to a hay diet, they had lower generic *E. coli* counts and total coliform counts than cattle fed a corn diet prior to slaughter. However, the research is inconclusive. Other studies have shown little to no reduction in fecal shedding of *E. coli* O157:H7. The research also shows that switching feedlot cattle from a high grain ration to hay during the last 5 days of finishing can result in a loss of an average of 2.2 lbs per head-per-day. Such a loss would have a negative impact on finishing cattle growth performance and carcass characteristics.

Additional references:

- Diez-Gonzalez F., T.R. Callaway, M.G. Kizoulis, J.B. Russell. 1998. Grain Feeding and the Dissemination of Acid-Resistant *Escherichia coli* from Cattle. *Science.* 281:1666-1668.
- Callaway, T.R., M.A. Carr, T.S. Edrington, R.C. Anderson, D.J. Nesbit. 2009. Diet, *Escherichia coli* O157:H7, and Cattle: A Review After 10 Years. *Curr. Issues Mol. Biol.* 11:67-80.
- Russell J.B., F. Diez-Gonzalez, G.N. Jarvis. 2000. Symposium: Farm Health and Safety Invited Review: Effects of Diet Shifts on *Escherichia coli* in Cattle Agricultural Research Service/USDA, and Section of Microbiology, Cornell University, Ithaca, NY.
- Russell J.B., F. Diez-Gonzalez, G.N. Jarvis. 2000. Invited Review: Effects of Diet Shifts on *Escherichia coli* in Cattle. *J. Dairy Sci.* 83(4):863-873.

- Stanton, T.L. and D. Schutz. 2000. Effect of switching from high grain to hay five days prior to slaughter on finishing cattle performance. Dept of Animal Sciences, Colorado State University.
- Jacob, M.E., J.T. Fox, S.K. Narayanan, J.S. Drouillard, D.G. Renter, T.G. Nagaraja 2008. Effects of feeding wet corn distillers grains with solubles with or without monensin and tylosin on the prevalence and antimicrobial susceptibilities of fecal foodborne pathogenic and commensal bacteria in feedlot cattle. *J Anim Sci.*86:1182-1190.
- Jacob, M.E, J.T. Fox, J.S. Drouillard, D.G. Renter, T.G. Nagaraja. 2008. Effects of Dried Distillers' Grain on Fecal Prevalence and Growth of *Escherichia coli* O157 in Batch Culture Fermentations from Cattle. *App. Env. Micro.* 74(1):38–43.
- Jacob, M.E., G.L. Parsons, M.K. Shelor, J.T. Fox, J.S. Drouillard, D.U. Thomson, D.G. Renter, T.G. Nagaraja. 2008. Feeding supplemental dried distiller's grains increases faecal shedding of *Escherichia coli* O157 in experimentally inoculated calves. *Zoonoses Public Health.* 55(3):125-32.
- Drouillaes, J.S. Distiller's Grains with solubles did not influence fecal shedding of *E. coli* O157:H7 in experimentally Inoculated Feedlot Steers. [www.beefresearch.org](http://www.beefresearch.org).
- Gordon, C.M., R.K. Phebus, J.S. Drouillard, H. Thippareddi, D.L. Lambert, K. Kerr, N. Pike, J.J. Sindt, J.J. Higgins. 2002. Dakota Gold Brand dried distiller's grains with soluble in finishing cattle diets: a preharvest strategy against acid resistant *Escherichia coli* and coliforms? *Cattlemans's Day.* pp. 56-61.
- Klopfenstein T.J., D.R. Smith, G.E. Erickson, R.A. Moxley, 2009. Feeding Distillers Grains and *E. coli* O157:H7. *Animal Science Department, Nebraska Beef Cattle Reports, University of Nebraska – Lincoln.* pp. 47-49.

### **C. Feeding Strategies**

Application: Abruptly feeding hay to cattle on a grain-based diet causes a shift in the available nutrients, thus selecting for organisms that displace *E. coli* O157:H7, thus preventing colonization of the intestines by *E. coli* O157:H7.

Findings: While an increase in the shedding of *E. coli* O157:H7 has been observed when cattle are fed poor quality forage or fasted, other researchers have observed a

reduction in *E. coli* O157:H7 when the diet is switched from a high grain ration to a high quality hay or low quality forage.

Additional references:

- Reinstein, S., J.T. Fox, X. Shi, M.J. Alam, D.G. Renter, T.G. Nagaraja. 2009. Prevalence of *Escherichia coli* O157:H7 in Organically and Naturally Raised Beef Cattle. *Appl. and Envir. Microbiol.* 75(16):5421-5423.
  - Gregory, N.G., L.H. Jacobson, T.A. Nagle, R.W. Muirhead, G.J. Lerouz Mirinz. 2000. Effect of preslaughter feeding system on weight loss, gut bacteria, and the physico-chemical properties of digesta in cattle. *New Zealand Journal of Agricultural Research.* 43:351-361.
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## **D. Fasting**

Application: Fasting of cattle before and during transportation is a common pre-harvest management practice to reduce hide contamination during transport and during slaughter processing.

Findings: Some research indicates that fasting may increase *E. coli* O157:H7 shedding. However, the reduction of ingesta present in the gastrointestinal tract prior to slaughter may be beneficial in decreasing fecal output, reducing the incidence of rumen spillage during carcass dressing, and thus reducing potential sources of carcass contamination.

Additional references:

- Jordan, D., and S.A. McEwen. 1998. Effect of duration of fasting and a short-term high-roughage ration on the concentration of *Escherichia coli* biotype 1 in cattle feces. *J. Food Prot.* 61:531–534.
  - Buchko, S.J., R.A. Holley, W.O. Olson, V.P.J. Gannon, D.M. Veira. 2000. The effect of fasting and diet on fecal shedding of *Escherichia coli* O157:H7 by cattle. *Can. J. Anim. Sci.* 80:741–744.
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## **Water and Food Additives**

### **(1) Seaweed Extract in Feed**

Application: Tasco-14 is an extract from the seaweed *Ascophyllum nodosum*, a known source of cytokinins with increased antioxidant activity. Currently, some beef producers feed the extract to cattle in commercial feedlots.

Findings: Research indicates that Tasco-14 may be effective in reducing *E. coli* O157:H7 shedding in cattle. Several university studies demonstrated that supplementing cattle diets with Tasco-14 for two weeks prior to slaughter resulted in fewer naturally occurring *E. coli* O157:H7 in the feces and on the hides of cattle.

Additional references:

- Barham, A.R., B.L. Barham, J.R. Blanton, V.G. Allen, K.R. Pond, F.M. Miller. 2001. Effects of Tasco #14 on prevalence levels of enterohemorrhagic *Escherichia coli* and *Salmonella spp.* in feedlot steers. *J. Anim. Sci.* 84, 257, 2001.
  - Braden, K.W., J.R. Blanton, V.G. Allen, K.R. Pond, M.F. Miller. 2004. *Ascophyllum nodosum* supplementation: a preharvest intervention for reducing *Escherichia coli* O157:H7 and *Salmonella spp.* in feedlot steers. *J. Food Prot.* 67:1824–1828.
  - Bach, S.J., Y. Wang, T.A. McAllister. 2008. Effect of feeding sun-dried seaweed (*Ascophyllum nodosum*) on fecal shedding of *Escherichia coli* O157:H7 by feedlot cattle and on growth performance of lambs. *Animal Feed Science and Technology.* 142:17–32.
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## **(2) Ractopamine**

Application: Ractopamine, a beta-agonist, is commercially available (OptaFlexx™) as a medicated feed additive. It is approved for use only in non-breeding cattle, specifically steers and heifers. The effect of Ractopamine in the animal is to redirect nutrients that would have become fat and synthesize them into protein. The protein is used to increase muscle fiber size, which helps increase lean meat yield.

Findings: Preliminary studies indicate a decrease in *E. coli* O157:H7 shedding in cattle.

Additional references:

- Edrington, T.S., T.R. Callaway, S.E. Ives, M.J. Engler, T.H. Welsh, D.M. Hallford, K.J. Genovese, R.C. Anderson, D.J. Nisbet, 2006. Effect of ractopamine HCl supplementation on fecal shedding of *Escherichia coli* O157:H7 and *Salmonella* in feedlot cattle. *Curr. Microbiol.* 53:340–345.
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### (3) Antibiotic Feed Additives

Ionophores, neomycin sulphate, tetracycline, and oxytetracycline are examples of antibiotics used in feed to reduce *E. coli* O157:H7 shedding in cattle. Ionophores are commercially available and routinely added to feed to increase feed efficiency in feedlot cattle. Some studies suggest that they may also reduce fecal shedding; however, most of the current research is inconclusive. Neomycin is FDA approved and has a 24-hour withdrawal. However, its use in cattle is controversial due to the risk associated with antimicrobial resistance and human health.

Findings: Most of the research does not indicate that neomycin sulphate, tetracycline, and oxytetracycline are effective at reducing of *E. coli* O157:H7 shedding in cattle. Some researchers consider neomycin a good candidate for use as a pre-harvest *E. coli* O157:H7 management control in feedlot cattle.

#### Additional references:

- Sargeant, J.M., M.W Sanderson, R.A. Smith, D.D. Griffin. 2004. Associations between management, climate, and *Escherichia coli* O157 in the faeces of feedlot cattle in the Midwestern USA. *Prev.Vet.Med.* 66:175-206.
- Elder, R., J. Keen, T. Wittum, T.R. Callaway, T.S. Edrington, R.C. Anderson, J. Nisbet. 2002. Intervention to reduce fecal shedding of enterohemorrhagic *Escherichia coli* O157:H7 in naturally infected cattle using neomycin sulfate. *Am. Soc. Anim. Sci./Am. Dairy Sci. Assoc. Joint Meet.* Quebec: 602.
- Woerner, D.R., J.R. Ransom, J.N. Sofos, J.A. Scanga, G.C. Smith, K.E. Belk. 2006. Preharvest processes for microbial control in cattle. *Food Prot. Trends.* 26:393–400.
- LeJeune, J.T. and A.N. Wetzel. 2007. Preharvest control of *Escherichia coli* O157 in cattle. *J. Anim. Sci.* 85:E73 – E80.

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### (4) Probiotics

**Key Point:** Research suggests that several probiotics preparations are effective in reducing *E. coli* O157:H7 shedding in cattle. Studies show that probiotics administered under the right conditions and using the correct methods are effective feed supplements for farm animals.

Applications: Probiotics preparations contain microorganisms or bacteria that are beneficial to the host animal. A variety of probiotic preparations are commercially available including *Lactobacillus acidophilus*. *Lactobacillus*-based direct-fed microbials are being used in feedlot finishing operations. Like antibiotics, a primary benefit of probiotics is to control intestinal infections in livestock. Beef producers must implement probiotics appropriately to avoid variable results.

Findings: Supplementing cattle diets with certain strains of *Lactobacillus acidophilus* in *Lactobacillus*-based direct-fed microbials is demonstrated to be effective in reducing shedding of *E. coli* O157:H7 in feedlot cattle. However, not all strains of *Lactobacillus acidophilus* effectively reduce the shedding of *E. coli* O157:H7 when used in a *Lactobacillus*-based direct-fed microbial.

Additional references:

- Sargeant, J.M., M.R. Amezcua, A. Rajic, L. Waddel. 2007. Pre-harvest interventions to reduce the shedding of *E. coli* O157 in the faeces of weaned domestic ruminants: a systematic review. *Zoonoses Public Health*. 54(6-7):260-277.
- Gilliland S. 2004. Probiotics Provide Benefits for Livestock. Food and Agriculture Products Center Oklahoma State University. [www.fapc.okstate.edu/files/flash/probiotics.pdf](http://www.fapc.okstate.edu/files/flash/probiotics.pdf)
- Brashears, M.M., M.L. Galyean, G.H. Loneragan, J.E. Mann, K. Killinger-Mann. 2003. Prevalence of *Escherichia coli* O157:H7 and performance by beef feedlot cattle given *Lactobacillus* direct fed microbials. *J. Food Prot.* 66:748–754.
- Elam, N.A., J.F. Gleghorn, J.D. Rivera, M.L. Galyean, P.J. Defoor, M.M. Brashears, S.M. Younts-Dahl. 2003. Effects of live cultures of *Lactobacillus acidophilus* (strains NP45 and NP51) and *Propionibacterium freudenreichii* on performance, carcass, and intestinal characteristics, and *Escherichia coli* strain O157 shedding of finishing beef steers. *J. Anim. Sci.* 81:2686–2698.
- Younts-Dahl, S.M., G.D. Osborn, M.L. Galyean, J.D. Rivera, G.H. Loneragan, M.M. Brashears. 2005. Reduction of *Escherichia coli* O157 in finishing beef cattle by various doses of *Lactobacillus acidophilus* in direct-fed microbials. *J. Food Prot.* 68:6–10.
- Stephens, T.P., G.H. Loneragan, E. Karunasena, M.M. Brashears. 2007. 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.* 70:2386-2391.

- Callaway, T.R., R.C. Anderson, T.S. Edrington, K.J. Genovese, K.M. Bischoff, T.L. Poole, Y.S. Jung, R.B. Harvey, D.J. Nisbet. 2004. What are we doing about *Escherichia coli* O157:H7 in cattle? J. Anim. Sci. 82 (E-Suppl): E93–E99.
  - LeJeune, J.T. and A.N. Wetzel. 2007. Preharvest control of *Escherichia coli* O157 in cattle. J. Anim. Sci. 85(E. Suppl.):E73–E80.
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### **(5) Colicin producing *E. coli* strains**

Applications: Colicins are antimicrobial proteins produced by certain strains of *E. coli* that can be effective in inhibiting the growth of *E. coli* O157:H7. Some strains can be effective in killing *E. coli* O157:H7 organisms. Use of colicin-producing *E. coli* strains, in feed or as direct fed products, may be effective in reducing fecal shedding of *E. coli* O157:H7.

Findings: Several strains of *E. coli* can produce colicins that are inhibitory, in vitro, to diarrheagenic *E. coli* strains, including strains of serotype O157 in cattle, and that can significantly reduce numbers of *E. coli* O157:H7 in weaned calves but not in neonatal calves. One study found that a daily dose of 10<sup>8</sup> CFU of colicin E7-producing *E. coli* per gram of feed can significantly reduce the fecal shedding of *E. coli* O157:H7 in cattle or calves. Colicin E7-producing *E. coli* can also significantly reduce the overall colonization of O157:H7 in the gastrointestinal tracts of the steers. Research on the application of colicin producing *E. coli* strains as a preharvest intervention in cattle is ongoing.

Additional references:

- LeJeune, J.T. and A.N. Wetzel. 2007. Preharvest control of *Escherichia coli* O157 in cattle. J. Anim. Sci. 85(E. Suppl.):E73–E80.
- Bradley, D.E., S.P. Howard, H. Lior. 1991. Colicinogeny of O157:H7 enterohemorrhagic *Escherichia coli* and the shielding of colicin and phage receptors by their O-antigenic side chains. Can. J. Microbiol. 37:97–104.
- Murinda, S.E., R.F. Roberts, R.A. Wilson. 1996. Evaluation of colicins for inhibitory activity against diarrheagenic *Escherichia coli* strains, including serotype O157:H7. Appl. Environ. Microbiol. 62:3196–3202.
- Zhao, T., M.P. Doyle, B.G. Harmon, C.A. Brown, P. O.E. Mueller, A.H. Parks, 1998: Reduction of carriage of enterohemorrhagic *Escherichia coli* O157:H7 in cattle by inoculation with probiotic bacteria. J. Clin. Microbiol. 36, 641–647.

- Tkalcic, S., T. Zhao, B.G. Harmon, M.P. Doyle, C.A. Brown, P. Zhao, 2003: Fecal shedding of enterohemorrhagic *Escherichia coli* in weaned calves following treatment with probiotic *Escherichia coli*. J. Food Prot. 66, 1184–1189.
  - Zhao, T., S. Tkalcic, M.P. Doyle, B.G. Harmon, C.A. Brown, P. Zhao. 2003. Pathogenicity of enterohemorrhagic *Escherichia coli* in neonatal calves and evaluation of fecal shedding by treatment with probiotic *Escherichia coli*. J. Food Prot. 66:924–930.
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## Management Practices and Transportation

**Key Point:** Sound management practices, including proper sanitation measures and pest control, can reduce levels of *E. coli* O157:H7 and other pathogens in the cattle's environment.

### (1) Clean and Dry Bedding

Clean and dry bedding may help prevent heavy soiling of the animal's brisket area. Keeping the brisket clean helps control contamination during slaughter. The brisket area is the site that contacts hands and knives when the initial cut is made at the start of the hide removal process during sanitary dressing procedures. A clean brisket may help control hide contamination and transmission of *E. coli* O157:H7 within the herd. Research suggests that clean bedding and housing does not reduce *E. coli* O157:H7 fecal shedding in cattle.

### (2) Sanitation Practices on Farms and Feedlots

The maintenance of clean clothes and equipment by farm and feedlot personnel can reduce the opportunities to transmit *E. coli* O157:H7 between herds on the same farm or feed lot. However, it does not reduce *E. coli* O157:H7 shedding in cattle.

Exclusion of animals other than livestock from access to cattle feed and water is a best practice. Insects, rodents, and other animals are known to be carriers of *E. coli* O157:H7. Pest management may reduce reservoirs of non-bovine sources of *E. coli* O157:H7 and reduce sources of contamination to water sources, feed, hides, and housing. However, the effects of wildlife exclusion, to the extent possible, on *E. coli* O157:H7 prevalence in cattle have not been fully researched.

### **(3) Housing**

Separate Housing of Calves and Heifers – Some research indicates that calves excrete *E. coli* O157:H7 more frequently and in greater numbers than adult animals. Separating calves from adults shows some effect in reducing prevalence and shedding of *E. coli* O157:H7 in calves. Housing calves away from other livestock may provide a mechanism to reduce *E. coli* O157:H7 in a dairy operation. However, separating calves is not practical in cow-calf operations. Off-site heifer raising is another option to reduce exposure of older cattle to the calves, but there may be biosecurity risks with bringing heifers back onto a farm.

Animal Density – A recent study reported a significantly greater *E. coli* O157:H7 prevalence in feedlot cattle housed at high density of cattle per area compared to cattle housed at a low density of cattle per area.

### **(4) Transportation**

Cross contamination between animals from different farms during transportation to the slaughter facility and at lairage can be an important source of hide contamination. Appropriate controls should be in place to minimize hide contamination.

Since transporting cattle may affect bacterial loads on the animal and, ultimately, on the carcass, recent research examined whether dust formed during cattle loading resulted in significant *E. coli* O157:H7 or *Salmonella* cross-contamination. The research showed that loading areas and dust generated during loading can increase pathogen loads on the animals before and after shipping.

Stress may play a role in the ability of *E. coli* O157:H7 to colonize the gastrointestinal tract and in *E. coli* O157:H7 fecal shedding. Stressful events, such as the stress associated with transportation, may be a factor in increased fecal shedding in cattle; however, current research is inconclusive.

#### Additional references:

- Cray, W.C., and H.W. Moon. 1995. Experimental infection of calves and adult cattle with *Escherichia coli* O157:H7. *Appl. Environ. Microbiol.* 61:1586–1590.
- Ahmad, A, T.G. Nagaraja, L. Zurek. 2007. Transmission of *Escherichia coli* O157:H7 to cattle by house flies. *Prev Vet Med.* 80:74-81.
- Hancock, D.D., T.E. Besser, D.H. Rice, E.D. Ebel, D.E. Herriott, L.V. Carpenter. 1998. Multiple sources of *Escherichia coli* O157 in feedlots and dairy farms in the Northwestern USA. *Prev Vet Med.* 35:11-19.

- Hegde, N.V., M.L. Cook, D.R. Wolfgang, B.C. Love, C.C. Maddox, B.M. Jayarao. 2005. Dissemination of *Salmonella enterica* subsp. *enterica* Serovar Typhimurium var. Copenhagen clonal types through a contract heifer-raising operation. J. Clin. Microbiol. 43:4208–4211.
  - Vidovic, S., and D.R. Korber. 2006. Prevalence of *Escherichia coli* O157 in Saskatchewan cattle: Characterization of isolates by using random amplified polymorphic DNA PCR, antibiotic resistance profiles, and pathogenicity determinants. Appl. Environ. Microbiol. 72:4347–4355.
  - M. Carr, Executive Director, Beef Safety Research and M. Rossman, Director, Beef Safety Research – NCBA, Issues Update. Special report: Beef safety research focuses on pre-harvest opportunities. May/June 2007. pp. 23-25.
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## Live Animal Treatments

### (1) Bacteriophages

Applications: Bacteriophages are FDA approved for use in or on live cattle as a treatment or for control of *E. coli* O157:H7 shedding in cattle. Bacteriophages (phages) are viruses that kill bacteria. A subset of bacteriophages can reduce bacterial loads in and on cattle and on the carcasses post-harvest.

FSIS has issued a no objection letter for the use of bacteriophages on the hides of cattle in holding pens prior to slaughter to control *E. coli* O157:H7 and *Salmonella*. Beef slaughterers may also use them on hides of cattle after slaughter, prior to skinning; however, researchers are still studying the efficacy of this intervention, and it is not commercially available.

Spraying or washing pre-slaughter and post-slaughter hides with bacteriophages is also possible but is rarely implemented because companies manufacturing bacteriophages have not yet developed a marketing strategy for pre-harvest applications for their products. At this time, companies producing bacteriophages consider post-harvest applications to be more effective and more cost beneficial than pre-harvest application and are concentrating marketing strategies on treating finished products.

Findings: One study suggests that the bacteriophage CEV1 shows promise as a component in a treatment for reduction of *E. coli* O157:H7 levels in food animals. Reducing *E. coli* O157:H7 in cattle by bacteriophage treatment is possible, but efforts to clear *E. coli* O157:H7 from cattle consistently with phage therapy may be unrealistic.

The commercial application of this pre-harvest intervention to aid in the control of *E. coli* O157:H7 in cattle is several years in the future.

Additional references:

- Abedon, S.T. 2008. Kinetics of Phage-Mediated Biocontrol of Bacteria. *Foodborne Pathogens and Diseases*. 6(7).
  - Bach, S.J., T.A. McAllister, D.M. Veira, V.P.J. Gannon, R.A. Holley. 2003. Effect of bacteriophage DC22 on *Escherichia coli* O157:H7 in an artificial rumen system (Rusitec) and inoculated sheep. *Anim. Res.* 52:89–101.
  - Kudva, I.T., S. Jelacic, P.I. Tarr, P. Youderian, C.J. Hovde. 1999. Biocontrol of *Escherichia coli* O157 with O157-specific bacteriophages. *Appl. Environ. Microbiol.* 65:3767–3773.
  - Tanji, Y., T. Shimada, M. Yoichi, K. Miyanaga, K. Hori, H. Unno. 2004. Toward rational control of *Escherichia coli* O157:H7 by a phage cocktail. *Appl. Microbiol. Biotechnol.* 64:270–274.
  - Raya R.R., P. Varey, R.A. Oot, M.R. Dyen, T.S. Edrington, E.M. Kutter, A.D. Brabban 2006. Isolation and characterization of a new T-even bacteriophage, CEV1, and determination of its potential to reduce *Escherichia coli* O157:H7 levels in sheep. *Appl. and Environ. Microbiol.* 72: 6405–6410.
  - Sheng H., H.J. Knecht, I.T. Kudva, C.J. Hovde 2006. Application of bacteriophages to control intestinal *Escherichia coli* O157:H7 levels in ruminants. *Appl. and Environ. Microbiol.* 72: 5359–5366.
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## **(2) Competitive Exclusion**

Applications: Researchers are developing ways to utilize competitive exclusion (CE) as a strategy to eliminate *E. coli* O157:H7 shedding in cattle. A pharmaceutical company recently received an investigational new animal drug (INAD) exemption from the Food and Drug Administration to use the product in cattle intended for use in human food. If beef producers use this product, there is a seven-day withdrawal time.

Findings: Researchers have isolated and defined multiple non-O157 *E. coli* strains from cattle and found that certain cultures could displace an established *E. coli* O157

population from the gastrointestinal tract of calves. Field trials have not yet been conducted.

Additional references:

- Zhao, T., S. Tkalcic, M.P. Doyle, B.G. Harmon, C.A. Brown, P. Zhao. 2003. Pathogenicity of enterohemorrhagic *Escherichia coli* in neonatal calves and evaluation of fecal shedding by treatment with probiotic *Escherichia coli*. J. Food Prot. 66:924–930.
  - Bradley, D.E., S.P. Howard, H. Lior. 1991. Colicinogeny of O157:H7 enterohemorrhagic *Escherichia coli* and the shielding of colicin and phage receptors by their O-antigenic side chains. Can. J. Microbiol. 37:97–104.
  - Brashears, M.M., D. Jaroni, J. Trimble. 2003. Isolation, selection, and characterization of lactic acid bacteria for a competitive exclusion product to reduce shedding of *Escherichia coli* O157:H7 in cattle. J. Food Prot. 66:355-63.
  - Moxley, R.A., D. Smith, T.J. Klopfenstein, G. Erickson, J. Folmer, C. Macken, S. Hinkley, A. Potter, B. Finlay. 2003. Vaccination and feeding a competitive exclusion product as intervention strategies to reduce the prevalence of *Escherichia coli* O157:H7 in feedlot cattle. Proc. 5th Int. Symp. on Shiga Toxin-Producing *Escherichia coli* Infections, Edinburgh, U.K.
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### **(3) Siderophore Receptor and Porin (SRP) Protein Vaccines**

Application: The United States Department of Agriculture (USDA) awarded conditional approval to EpiToxix, the SRP Protein vaccine technology, for use to reduce *E. coli* O157:H7 shedding. A conditional license means a company can market the product, but that the USDA still requires additional safety and efficacy tests. The vaccine must be used under the direction of a veterinarian and is marketed as a three-dose vaccine.

EpiToxix™ SRP protein type vaccine targets the iron requirement of pathogenic gram-negative bacteria, such as *E. coli* O157:H7 and *Salmonella*, causing disruption of the bacteria's iron transport system, which ultimately causes death of the organism. The vaccine blocks the bacteria from absorbing iron and, without iron, the bacteria die.

Findings: In general, the efficacy of vaccinating cattle for *E. coli* O157:H7 is still questionable, and research is ongoing. Researchers are currently studying the minimum amount of vaccine and number of doses necessary to ensure maximum effectiveness in reducing the *E. coli* O157:H7 in cattle when using SRP vaccines.

Researchers have found the vaccine is effective at controlling *E. coli* O157:H7 shedding in cattle.

Additional references:

- Thornton A.B., D.U. Thomson, G.H. Loneragan, J.T. Fox, D.T. Burkhardt, D.A. Emery, T.G. Nagaraja. 2009. Effects of a siderophore receptor and porin proteins-based vaccination on fecal shedding of *Escherichia coli* O157:H7 in experimentally inoculated cattle. *J Food Prot.* 2:866-869.
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#### **(4) Bacterial Extract Vaccines**

Application: Econiche™ is a bacterial extract vaccine licensed for use in Canada. Bioniche Life Sciences Inc. of Belleville Ontario, Canada received full licensing approval for the use of Econiche from the Canadian Food Inspection Agency in October 2008. Econiche™ is not licensed in the United States. However, Bioniche Life Sciences Inc., has petitioned USDA for a conditional license for the use Econiche™ in the U.S. A conditional license is expected to be issued in the near future.

Econiche™ is a three-dose vaccine. Feedlot practices in the U.S.A. do not easily accommodate a three-dose vaccination treatment. However, the technical information link for Econiche™ includes information regarding the effectiveness of the vaccine when administered as a 2-dose vaccination treatment. Studies suggest that the efficacy of the vaccine is dose-dependent.

Findings: Several published articles support the efficacy of Econiche™. One study found that vaccinating feedlot cattle three times at three-week intervals against Type III secretory proteins of *E. coli* O157:H7 reduced the probability of fecal shedding of the *E. coli* O157:H7 by 59%.

Additional resources:

- Potter, A.A., S. Klashinsky, Y.Li, E. Frey, H. Townsend, D. Rogan, G. Erickson, S. Hinkley, T. Klopfenstein, R. A. Moxley, D. R. Smith, B.B. Finlay. 2004. Decreased shedding of *Escherichia coli* O157:H7 by cattle following vaccination with type III secreted proteins. *Vaccine* 22:362–369.
- Peterson, R.E., D.R. Smith, R.A. Moxley, T.J. Klopfenstein, S. Kinkley, G.E. Erickson. 2005: Vaccination for *Escherichia coli* O157:H7 in market ready feedlot cattle, pp. 61–63. Nebraska Beef Report, University of Nebraska, Lincoln.

- Van Donkersgoed, J., D. Hancock, D. Rogan, A.A. Potter. 2005. *Escherichia coli* O157:H7 vaccine field trial in 9 feedlots in Alberta and Saskatchewan. *Can. Vet. J.* 46:724–728.
  - Moxley R.A., D.R. Smith, M. Luebbe, G.E. Erickson, T.J. Klopfenstein, D. Rogan. 2009. *Escherichia coli* O157:H7 vaccine dose-effect in feedlot cattle. *Foodborne Pathog Dis.* 6:879-84.
  - Moxley, R.A., D.R. Smith, K. Hansen, M.K. Luebbe, G.E. Erickson, T.J. Klopfenstein, D. Rogan. 2008 Vaccination for *Escherichia coli* O157:H7 in Feedlot Cattle. *Animal Science Department, Nebraska Beef Cattle Reports, University of Nebraska - Lincoln Year 2008*, pp. 102-104.
  - Smith, D.R., R.A. Moxley, T.J. Klopfenstein, E.G. Erickson. 2009. A randomized longitudinal trial to test the effect of regional vaccination within a cattle feedyard on *E. coli* O157:H7 rectal colonization, fecal shedding and hide contamination. *Foodborne Pathog Dis.* 6(7):885-892.
  - Smith, D.R., R.A. Moxley, R.E. Peterson, T.J. Klopfenstein, G.E. Erickson, G. Bretschneider, E.M. Berberov, S. Clowser. 2009. A Two-Dose Regimen of a Vaccine Against Type III Secreted Proteins Reduced *Escherichia coli* O157:H7 Colonization of the Terminal Rectum in Beef Cattle in Commercial Feedlots. *Foodborne Path. and Dis.* 6:155-161.
  - Rogan, D.R., D.R. Smith, R.A. Moxley, A.A. Potter, C.E. Strauss. Vaccination with Type III secretion proteins reduces *E. coli* O157:H7 shedding and contamination in cattle. *Vet. Immun.and Immunopath.* 128(1-3):334.
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## **(5) Cattle Hide Washing**

Finding: Hide washes are a very effective method to remove visible debris from hides as well as reducing the pathogen load on cattle hides in the live animal prior to slaughter or immediately after slaughter. It does not have any effect in reducing *E. coli* O157:H7 fecal shedding in cattle.

Application: A Beef Checkoff funded study of hide washing systems resulted in the development of Trichloromelamine – a non-toxic, biodegradable hide wash intervention that reduces foodborne pathogens on beef cattle hides by 50 percent.

Additional references:

- Edrington, T.S., T.R. Callaway, R.C. Anderson, K.J. Genovese, Y.S. Jung, F.L. McReynolds, K.M. Bishoff, D.J. Nisbet, 2003. Reduction of *E. coli* O157:H7 populations in sheep by supplementation of an experimental sodium chlorate product. *Small Rum. Res.* 49:173–181.

## Attachment 1      What is *E. coli* O157:H7?

*Escherichia coli* (*E. coli*) bacteria live in the intestines of healthy cattle and have a symbiotic relationship with the cattle, an association where the *E. coli* derives benefit and cattle are not harmed. However, several strains of *E. coli* have evolved from being mildly pathogenic in human to being highly pathogenic and capable of causing death when they infect humans.

*E. coli* O157:H7 is a strain of Enterohemorrhagic *Escherichia coli* (EHEC) Shiga toxin-producing *Escherichia coli* (STEC) associated with cattle and disease in humans. O157 is best known as the Enterohemorrhagic *E. coli* (EHEC) strain, being responsible for most of the EHEC human illnesses and interest (research and media articles) in the United States. Worldwide, however, STEC serotypes (e.g., members of the O26, O91, O103, O111, O118, O145, and O166 serogroups) have been isolated from beef and found to cause human illnesses ranging from bloody diarrhea and hemorrhagic colitis to the life-threatening hemolytic uremic syndrome. There are at least six well characterized types of *E. coli* that can cause intestinal disease in humans. FSIS does not ignore the other EHEC strains, but most of the research in the U.S. has been specific to *E. coli* O157:H7. The other serotypes of EHEC can also cause disease in humans and some are the primary EHECs causing human illness in other countries.

*E. coli* O157:H7 can cause hemorrhagic colitis and hemolytic uremic syndrome in human. *E. coli* O157:H7 is the strain of human pathogenic *E. coli* bacteria of primary interest to FSIS USDA due to:

1. Its presence on the hide and in the gut of cattle presented for slaughter;
2. A low infectious dose is capable of causing severe human disease and death associated with consumption of under cooked non-intact beef products, such as ground beef;
3. Its presence as a contaminant in raw beef component used to make ground beef; and
4. Ground beef is the most frequently implicated source of *E. coli* O157:H7 outbreaks in the United States.

Since 1994 when FSIS declared *E. coli* O157:H7 to be an adulterant in ground beef, the beef industry has invested time, effort, and research on post-harvest interventions (best slaughter, dressing, and fabrication practices) to reduce the presence of *E. coli* O157:H7 in raw ground beef products. The beef industry control and reduce *E. coli* O157:H7 by focusing their efforts on effective sanitary dressing practices (e.g., skinning and evisceration), treating beef carcasses with chemical or physical interventions during slaughter and dressing operations, and by using sanitary practices during fabrication of

trim and ground beef products to minimize cross contaminations of ground beef product lots.

These post-harvest in-plant efforts have reduced *E. coli* O157:H7 contamination on carcasses that may occur during carcass dressing. However, several studies have highlighted the importance of the *E. coli* O157:H7 load on feedlot cattle entering slaughter establishments as a critical factor for determining the level of *E. coli* O157:H7 contamination on dressed carcasses and eventually in ground beef. These studies suggest that if the *E. coli* O157:H7 load on cattle entering the slaughter establishments is reduced, there would be a corresponding reduction in the *E. coli* O157:H7 on carcass and in ground beef.

**NOTE:** In addition to EHEC, cattle are reservoirs of several food borne pathogens that include *Campylobacter* spp., *Cryptosporidium* spp., *Listeria* spp. and *Salmonella* and also of several emerging human diseases, such as *Helicobacterium pylori* and *Mycobacteria paratuberculosis*.

## **Attachment 2: Ecological and Epidemiological Characteristics of *E. coli* O157:H7**

### Distribution:

1. Transient residence in the gastrointestinal flora of individual animals that is not associated with clinical disease;
2. Pervasive in animals and ubiquitous in cattle;
3. Microbial counts in the colon and rectum were higher than in any other location in the gastrointestinal tract of cattle, and *E. coli* O157:H7 has a preference for the hindgut and not the rumen;
4. Persists in many different environments remaining viable in water, soil, and feces for several months; and
5. Lack of host specificity such that indistinguishable isolates can be found in a variety of species.

### Prevalence:

1. Higher during warm months;
2. Higher in calves than mature cattle; and
3. Higher prevalence in animals with rumen floral disturbance (feed changes, antimicrobial dosing, transportation).

### Incidence:

1. Temporal clustering with a sharp spike in a high percentage of animals separated by much longer periods of very low prevalence; and
2. Transient residence in the gastrointestinal flora of individual animals that is not associated with clinical disease.

**Attachment 3: Summary Table of Pre-harvest Practice Management and Intervention Options for Control of *Escherichia coli* O157:H7**

<b>A. Water and Feed</b>	
<b>1. Water Treatments</b>	Chlorination at 2 – 5 ppm is an effective and inexpensive means of reducing total <i>E. coli</i> counts in drinking water. The presence of organic matter reduces its effectiveness. It can be difficult to maintain adequate chlorine levels for it to be consistently effective.
	Electrolyzed water has been shown to be effective in killing <i>E. coli</i> O157:H7 under experimental conditions; it has not been tested under field conditions. Special equipment is required.
	Ozonation is an FDA approved process for disinfecting drinking water. Special equipment is required.
<b>2. Feed Types and Feed Strategies</b>	Fasting of cattle prior to slaughter can reduce fecal output and reduce fecal soiling in the environment and on the hide. Some studies have shown an increase in <i>E. coli</i> O157:H7 shedding in fasting cattle.
	Grain vs. forage diets: in general, research supports that cattle on grain-based diets appear to shed higher levels of generic <i>E. coli</i> in their feces than cattle on forage diets but is inconclusive as to its effect on fecal shedding of <i>E. coli</i> O157:H7.
	Hay: abrupt feeding of hay to cattle on a grain based diet can prevent colonization of <i>E. coli</i> O157:H7 in the intestines. Some studies have shown an increase in shedding in cattle fed poor quality forage.
<b>B. Water and Feed Additives</b>	
<b>1. Antibiotics</b>	Some individual antibiotics have been shown to be effective in reducing fecal shedding of <i>E. coli</i> O157:H7 but there is no significant consistent positive association noted. There are concerns

	<p>about the risk associated with the development of antibiotic resistance to some antibiotics which may have a negative impact on human health. Residue concerns may delay slaughter eligibility due to compliance with drug withdrawal times.</p>
<b>2. Probiotics</b>	<p>Research supports the efficacy of some combinations of probiotic bacteria strains. There is no systemic absorption and no concerns of drug residues with their use. They must be administered under the right conditions and using the correct method of administration to be effective.</p>
<b>3. Colicin-producing <i>E. coli</i> strains</b>	<p>Use of colicin-producing <i>E. coli</i> strains, in feed or as direct fed products, may be effective in reducing fecal shedding of <i>E. coli</i> O157:H7.</p>
<b>4. Seaweed Extract (Tasco – 14)</b>	<p>When used as a feed supplement for two weeks prior to slaughter, it results in fewer naturally occurring <i>E. coli</i> O157:H7 in the feces and on the hides of cattle.</p>
<b>5. Ractopamine</b>	<p>Preliminary studies have demonstrated a decrease in fecal shedding of <i>E. coli</i> O157:H7 and <i>Salmonella</i> in cattle. A feed supplement approved for use to improve cattle quality and performance. Currently not approved for use for this application.</p>
<b>C. Live Animal Treatments</b>	
<b>1. Bacteriophage</b>	<p>Bacteriophages are FDA approved for use in or on live cattle as a treatment or for control of <i>E. coli</i> O157:H7 shedding in cattle.</p>
	<p>Application to cattle hides can reduce bacterial loads on the treated animal.</p>
<b>2. Competitive Exclusion (CE)</b>	<p>Can be an effective means to interfere with the ability of <i>E. coli</i> O157:H7 to adhere to the intestinal lining and populate the gut. Several products are under research and development.</p>

<b>3. Vaccines</b>	Studies of two types of vaccines have demonstrated that vaccines can be effective in reducing colonization and adherence of <i>E. coli</i> O157:H7 in the intestinal tract and reduce fecal shedding in vaccinated cattle. The efficacy and safety of the vaccines are still being validated.
<b>4. Hide washing</b>	Hide washing can be effective in removing visible debris from hides prior to carcass dressing. Applications in the live animal may be limited due to humane handling concerns and worker safety. Application in cattle immediately after stunning may be more practical.
<b>D. Management Practices and Transportation</b>	
<b>1. Clean and Dry Bedding</b>	May help prevent heavy soiling of the brisket area of cattle, decreasing the potential for contamination during carcass dressing. Inconclusive evidence as to whether it reduces transmission of <i>E. coli</i> O157:H7 within the herd.
<b>2. Sanitation Practices on Farms and Feedlots</b>	Maintaining good hygiene practices among farm and feedlot workers and sanitation of equipment and premises may prevent cross contamination between and within cattle herds.
<b>3. Pest Management</b>	Control of insect, bird, rodent and other pest populations may reduce reservoirs of non-bovine sources of <i>E. coli</i> O157:H7 and reduce sources of contamination to water, feed, housing and hides.
<b>4. Maintain Closed Herds</b>	Maintaining cattle in closed herds reduces social stress and reduces potential for cross contamination between herds. Reducing stress may help to reduce fecal shedding of <i>E. coli</i> O157:H7.

<b>5. Transportation</b>	Cross contamination between animals from different farms or feedlots during transportation to the slaughter plant and at lairage can be an important source of hide contamination. Stress of handling and transportation may affect fecal shedding of <i>E. coli</i> O157:H7 in individual cattle.
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