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**Pre-Harvest Management Controls and Intervention Options for  
Reducing Shiga Toxin-Producing *Escherichia coli* Shedding in Cattle:  
An Overview of Current Research**

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## I. Introduction and Background Discussion

This document is being reissued to provide beef slaughter establishments with an informational resource on pre-harvest management controls and interventions for reducing Shiga toxin-producing *E. coli* (STEC) shedding in beef cattle production. The document was first issued as “Pre-harvest Management Controls and Intervention Options for Reducing *Escherichia Coli* O157:H7 Shedding in Cattle, May 2010” ([FR Doc. 2010–11545](#)) to address *E. coli* O157:H7, which the Food Safety and Inspection Service ([FSIS](#)) declared as an adulterant in ground beef in 1994. In September 2011, FSIS declared six additional STEC strains – O26, O45 O103, O111, O121, and O145 – as adulterants in beef. Thus, all non-intact beef products or intact beef products that are to be further processed into non-intact beef products before distribution for consumption are adulterated if found to be contaminated with STEC O157:H7, O26, O45, O103, O111, O121, or O145 within the meaning of the Federal Meat Inspection Act (FMIA). FSIS has updated this document to include discussion of the non-O157 STEC in addition to O157:H7. Many establishments that produce raw non-intact beef products implement controls for *E. coli* O157:H7. These methods should be as effective in controlling non-O157 STEC as in controlling *E. coli* O157:H7.

Following publication of the May 2010 guideline, FSIS received several comments that suggested the document lacked scientific rigor, was inconsistent in the recommendations provided in the studies, and generally included practices that did not work. For example, the guideline included a number of studies on feed types, feed additives, fasting, and their effects on *E. coli* O157:H7 fecal shedding, with some studies showing a decrease in fecal shedding while others showed an increase or no difference in fecal shedding. In some studies, ractopamine was shown to decrease *E. coli* O157:H7 fecal shedding, while in other studies it was shown to increase fecal shedding. Some thought the issuance was premature, would be impractical to implement, and should be withdrawn until the science exists that demonstrates viable options for reducing pathogen shedding in cattle. The Agency’s intent in issuing the May 2010 document and, as stated, in re-issuing it now is to provide industry with a review of the literature and current status of pre-harvest interventions, management practices, and ongoing research. FSIS has removed statements from the document that may have recommended any particular pre-harvest intervention or practice over another one. There is no regulatory requirement for establishments to use the interventions or management practices outlined in this document.

### Pre-harvest Food Safety for Cattle Public Meeting

The U.S. Department of Agriculture ([USDA](#)) held a public meeting in November 2011 in Riverdale, MD, to explore innovative ways to control pathogens in beef at pre-harvest. FSIS, the Animal and Plant Health Inspection Service ([APHIS](#)), and the Agricultural Research Service ([ARS](#)) convened the meeting to discuss how pre-harvest pathogen control strategies for animals presented for slaughter can reduce the likelihood that beef could become contaminated with STEC, *Salmonella*, and other pathogens. The meeting

featured presentations on the latest research and included three break-out sessions to address the following questions:

1. What factors influence the shedding of *Salmonella* and *E. coli* O157:H7 and other STEC (e.g., age of cattle, stress conditions)?
2. What effective and practical mitigations are available to reduce the pathogen load in general, and *Salmonella* and STEC specifically, in cattle before slaughter?
3. How can producers, processors, and government work together to promote adoption of pre-harvest food safety mitigations?

Meeting participants sought clarification of what super shedders are, and how they would be identified during production. They felt strongly that the United States should build upon successful mitigations used in foreign countries, allow the market to drive the value of any particular mitigation technology including vaccines, and streamline the regulatory approval process. They recommended also that there be sustained discussions among federal, industry, and academic partners to identify and put into practice pre-harvest mitigations for reducing foodborne hazards in beef. The meeting agenda, transcript, and participant's response to the questions can be found on the FSIS web site at: <http://www.fsis.usda.gov/wps/portal/fsis/newsroom/meetings/past-meetings/past-meetings-2011>.

As discussed, this document provides innovative ways to control pathogens in beef at pre-harvest and pre-harvest pathogen control strategies for animals presented for slaughter. The application, state of the findings, and links to additional scientific references are provided for the strategies discussed.

### Food Safety Hazards

Federally inspected establishments are required to conduct a hazard analysis as part of their Hazard Analysis and Critical Control Point (HACCP) system. The hazard analysis is required to include 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 and can continue in the holding pens at the establishment. This fecal shedding may result in contamination of the hides, and the contamination can subsequently be transferred to the carcass during carcass dressing. Establishments may address this hazard by incorporating purchase specifications, other programs, or agreements as part of their HACCP plans or prerequisite programs to require that their suppliers implement certain pre-harvest management controls. These programs, designed to support decisions in the hazard analysis, are part of the HACCP system.

### Pre-harvest Management Practices and Interventions

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.

This document describes several pre-harvest interventions and management practices and the state of the findings about these practices. Research on pre-harvest interventions for STEC is ongoing. Most of the research has focused on *E. coli* O157:H7 but has potential for reducing other strains of STEC. Therefore, this document focuses primarily on research conducted for *E. coli* O157:H7. 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 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 consider its use in designing their food safety systems. FSIS will continue to monitor this type of research and update this document as needed.

## Veal

FSIS test results show that the percent positive for STECs from trimmings produced from veal appears to be higher than from trimmings produced from other cattle slaughter classes since the Agency began testing the six additional STECs in June 2012. In January 2013, FSIS consulted the National Advisory Committee on Meat and Poultry Inspection about the higher numbers seen in veal operations. The committee recommended that the Agency confer with ARS or other research providers to conduct research into pre-harvest risk factors associated with STEC in veal slaughter. The committee also recommended that the Agency promote research into the development of industry best management practices. The committee concluded with the following statement that is being considered by the Agency:

Recognizing that pre-harvest practices can impact potential pathogen contamination, the Agency should conduct a series of stakeholder meetings to facilitate knowledge sharing and capturing to more fully fill the data gap that exists for this specific class of beef. The committee encourages the agency to investigate and develop recommendations for pre-harvest interventions and . . . ensure discussions with interested stakeholder meetings on this topic. Further, the committee recognizes potential differences between the subgroups bob veal and formula fed veal within the veal class and recommends the agency focus its efforts at the stakeholder meetings on this topic with intent to capture both optimum in-plant sanitary dressing procedures and pre-harvest best practices.

[http://www.fsis.usda.gov/wps/wcm/connect/1937a01a-7478-4d5d-9d48-16b237f19a1e/NACMPI\\_Transcript\\_Subcmt1\\_011613.pdf?MOD=AJPERES](http://www.fsis.usda.gov/wps/wcm/connect/1937a01a-7478-4d5d-9d48-16b237f19a1e/NACMPI_Transcript_Subcmt1_011613.pdf?MOD=AJPERES)

## Background Information on STEC Shedding in Cattle

*E. coli* O157:H7 is a food safety hazard well documented in scientific research. [Appendix 1](#), “What is Shiga toxin-producing *E. coli*?” and [Appendix 2](#), “Ecological and Epidemiological Characteristics of *E. coli* O157:H7,” provide general information regarding the pathogen. [Appendix 3](#) is a quick reference table that summarizes the pre-harvest management options and interventions presented in this document.

As suggested in some scientific literature, pre-harvest practices and interventions are grouped into three categories in this document: (1) exposure reduction strategies (environmental management), (2) exclusion strategies (treatments such as dietary and vaccination modifications), and (3) direct anti-pathogen strategies (certain types of treatments such as bacteriophages).

### Request for comments

This document is a revision of a previous guidance document. As such, it is not subject to the Office of Management and Budget's (OMB) "Final Bulletin for Agency Good Guidance Practices" (GGP). More information can be found on the FSIS web site: <http://www.fsis.usda.gov/wps/portal/footer/policies-and-links/significant-guidance-documents>. However, FSIS is seeking comments on this document as part of its efforts to continuously assess and improve the effectiveness of policy documents. The comments will be considered for future revisions of this document.

FSIS requests that all interested persons submit comments regarding any aspect of this document, including but not limited to: content, readability, applicability, and accessibility. Comments may be submitted by either of the following methods:

(1) Online submission at [regulations.gov](http://www.regulations.gov): 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> and follow the instructions for submitting comments.

(2) Mail, including floppy disks or CD-ROMs, and hand- or courier-delivered items: Send to Docket Clerk, U.S. Department of Agriculture (USDA), FSIS, Patriots Plaza 3, 1400 Independence Avenue SW, Mailstop 3782, 8-163A, Washington, DC 20250-3700.

All items submitted by mail or electronic mail must include the Agency name, FSIS, and document title **Pre-Harvest Management Controls and Intervention Options for Reducing Shiga Toxin-Producing Escherichia coli Shedding in Cattle: An Overview of Current Research, August 2014**. Comments received in response to this document will be made available for public inspection and posted without change, including any personal information, to <http://www.regulations.gov>.

**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.

## II. EXPOSURE REDUCTION STRATEGIES

The goal of exposure reduction strategies is to reduce the frequency of exposure of cattle to contaminated sources in the environment, thereby reducing the prevalence of STEC in live animals.

### Pre-Harvest Cattle Management Controls

Pre-harvest cattle management controls and interventions are emerging as an option that offers great opportunity to improve food safety. The beef industry is investigating production

**Basic recommended principles of cattle management to reduce spread of particular strains of *E. coli* in the production cycle:**

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

practices that reduce food safety risks. The beef 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.

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 heifers or reduced animal density; and
5. Biosecurity—wildlife exclusion to the extent possible.

FSIS supports the principles of good pre-harvest management control because they provide the foundation for the processing interventions and sanitary dressing procedures used to control *E. coli* O157:H7 contamination in raw beef.

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## Management Practices and Transportation

### (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.

### (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 or between cattle 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 such as sheep and deer 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.

### (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 beef cow-

### Management Practices and Transportation

- (1) Clean and Dry Bedding
- (2) Sanitation Practices on Farms and Feedlots
- (3) Housing
- (4) Transportation

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 among animals from different farms during transportation to the slaughter facility and at lairage (holding pens) can be an important source of hide contamination. Therefore, appropriate controls should be in place to minimize hide contamination.

Recent 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, one study suggested that the feedlot pen has a greater effect on hide contamination at the slaughter plant than transportation factors including temperature-humidity index, loading density, and duration of transport.

**Key Point:**  
Reductions in the pathogen loads of cattle entering the slaughter plant will cause a reduction in foodborne pathogens on carcasses and in beef products, resulting in a safer product for the consumer.

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### III. EXCLUSION REDUCTION STRATEGIES

The goal of exclusion reduction strategies is to modify or change the microhabitat of the gastrointestinal tract of cattle so STEC will not be established or will be displaced by bacteria less harmful to humans.

#### Cattle Water and Feed Management

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

Application: 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 an 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.

**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.

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.

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## (2) Cattle Feed Types and Feeding Strategies

### A. Feed Types

**Feed Types and Feeding Strategies:** 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. However, there is no conclusive evidence that feeding cattle forage is consistently effective at reducing pathogens under field conditions.

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

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

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Findings: A significant amount of research has been conducted, but there is no conclusive evidence that feeding cattle forage is consistently effective at reducing pathogens under field conditions. Grains such as barley and distillers grains have been shown to increase *E. coli* O157:H7 shedding in cattle. Studies have shown that even the form of corn fed to cattle can affect *E. coli* O157:H7 shedding. Cattle fed steam-flaked corn shed more *E. coli* O157:H7 than those fed dry-rolled corn because of the passage of more starch to the hindgut where it is fermented to produce volatile fatty acids that kill *E. coli* O157:H7. Calves fed on grain-based diets shed more *E. coli* O157:H7 than those fed on a forage diet. While *E. coli* O157:H7 populations tend to be lower in cattle fed forage, pathogens are still found in cattle fed forage. Although some have claimed that grass-fed cattle have fewer pathogens than grain-fed cattle, researchers have found no significant food safety differences in grass-fed cattle versus corn-fed cattle.

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## B. Feeding Strategies

**Application:** Most US beef producers feed cattle a grain finishing diet. 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 and preventing colonization of the intestines by *E. coli* O157:H7. Some factors intrinsic to forage may explain some of the observations and inconsistencies found between forage and grain-based diets.

**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 were switched to a hay diet, they had lower generic *E. coli* counts and total coliform counts than cattle fed a corn diet before slaughter. It has been suggested that the fiber component of hay may scrape the gut wall, physically removing the organism and contributing to reduced colonization and shedding. 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. An increase in *E. coli* O157:H7 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:H7 shedding when the diet is switched from a high grain ration to a high quality hay or low quality forage.

**Feeding Strategies:** Sudden shifts in feeding practices – from grain to hay – may cause disruption in the microbial population of the gut, resulting in a decrease in *E. coli* counts in the gut.

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## C. Fasting

Fasting cattle before and during transportation reduces hide contamination during transport and slaughter processing.

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: Most research indicates that fasting may increase *E. coli* O157:H7 shedding. However, the reduction of ingesta present in the gastrointestinal tract before 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.

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## Water and Feed 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 for various reasons, such as to improve carcass quality.

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 before slaughter resulted in fewer naturally occurring *E. coli* O157:H7 in the feces and on the hides of cattle.

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## (2) Ractopamine

**Application:** Ractopamine, a beta-agonist, is commercially available (OptaFlexx™) as a 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. A 2006 study showed that when feedlot cattle were fed ractopamine, the number of cattle shedding *E. coli* O157:H7 decreased. However, a 2011 study showed that ractopamine had no effect on fecal prevalence of *E. coli* O157:H7. In Russia, beta agonists cannot be used in beef.

**Findings:** Preliminary studies indicated a decrease in *E. coli* O157:H7 shedding in cattle, but later studies indicated that ractopamine had minimal effect on fecal shedding of *E. coli* O157:H7.

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## (3) Antibiotic Feed Additives

**Application:** Antibiotics such as ionophores, neomycin sulfate, tetracycline, and oxytetracycline are used in cattle feed for various purposes. Antibiotics have been suggested as a means 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. Ionophores are not used in human medicine, so use of ionophores in cattle is not viewed as a concern with regard to development of antimicrobial resistant pathogens. Other antibiotics that are used in cattle feed for disease prevention, such as neomycin, oxytetracycline, and chlortetracycline, have uses in human medicine. Thus, their use in cattle to reduce *E. coli* O157:H7 shedding is controversial because of 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. Some studies suggest that ionophores reduce *E. coli* O157:H7 shedding in certain circumstances.

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#### (4) Probiotics

**Application:** 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.

**Key Point:** Research suggests that several probiotic 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.

**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.

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### (5) Colicin-producing *E. coli* strains

**Application:** 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:H7 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 pre-harvest intervention in cattle is ongoing. These products are not being used currently by producers, primarily because they are expensive.

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## IV. DIRECT ANTI-PATHOGEN STRATEGIES

The goal of direct anti-pathogen strategies is to target and kill the STEC.

### (1) Cattle Hide Washing

Application: 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 before slaughter or immediately after slaughter. It does not have any effect in reducing *E. coli* O157:H7 fecal shedding in cattle.

Findings: 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.

**Key Point:** Hide washes significantly reduce the bacterial load on cattle hides entering the plant for slaughter.

In a study published in 2012, researchers at the United States Department of Agriculture's Agricultural Research Service (ARS), tested hypobromous acid (HOBr) as an antimicrobial treatment on hides at two concentrations, 220 and 500 ppm. At 220 ppm, HOBr reduced the prevalence of *E. coli* O157:H7 on hides from 25.3 to 10.1%. At 500 ppm, HOBr reduced the prevalence of *E. coli* O157:H7 on hides from 21.2 to 10.1%. *Salmonella* and aerobic plate counts, total coliform counts, and generic *E. coli* counts were also reduced. This study suggests that adoption of HOBr as a hide wash will reduce spoilage bacteria and pathogen prevalence, resulting in lower risk of carcass contamination.

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## **(2) 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.

In 2006, FSIS issued a no-objection letter for the use of bacteriophages on the hides of cattle in holding pens before slaughter to control *E. coli* O157:H7 and *Salmonella*. Beef slaughterers may also use them on hides of cattle before skinning. In February 2012, FSIS issued a no-objection letter for the use of an *E. coli* O157:H7 bacteriophage on the hides of cattle within lairage or holding pens, restraining areas, stunning areas, and stations immediately before hide removal. Shortly thereafter, in April 2012, FSIS issued a letter of no-objection for use of a STEC targeted bacteriophage cocktail that is effective for *E. coli* serogroups O157, O26, O45, O103, and O145 applied in the same manner as the one for *E. coli* O157:H7.

Killing pathogens on hides before removal is an effective way of reducing carcass contamination. Spraying or washing hides with bacteriophages is being used more widely at pre-harvest as more companies develop a marketing strategy for pre-harvest applications of their products. Finalyse® is a commercially available bacteriophage cocktail sprayed on cattle before their entering the establishment to reduce the load of *E. coli*.

Findings: A 2006 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 may be a few years in the future.

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### (3) Competitive Exclusion

#### **Competitive Exclusion Principle:**

When two species compete for the same critical resources within an environment, one of them will eventually outcompete and displace the other.

Application: 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: In a 2003 study, researchers isolated and defined several *E. coli* strains including *E. coli* O157:H7 from cattle and found that certain cultures could displace an established *E. coli* O157 population in live cattle and reduce fecal shedding of *E. coli* strains in calves. Field trials have not yet been conducted.

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### (4) Siderophore Receptor and Porin (SRP) Protein Vaccines

Application: The USDA awarded conditional approval to Epitopix LLC for an *E. coli* bacterial extract vaccine using 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. Epitopix™ 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: Although the efficacy of vaccinating cattle for *E. coli* O157:H7 is still being questioned, and research is ongoing, a scientific study published in 2012 indicates that the SRP vaccine significantly reduces fecal prevalence of *E. coli* O157:H7 and prevalence of high shedders. SRP looks promising as an effective intervention for *E. coli* O157:H7 control in commercial feedlots.

Researchers are currently studying the minimum amount of vaccine and number of doses necessary to ensure maximum effectiveness in reducing *E. coli* O157:H7 in cattle when using SRP vaccines. The vaccine is commonly administered in three doses. Feedlot practices in the U.S. do not easily accommodate a three-dose vaccination treatment. The same 2012 study cited in the paragraph above indicates effectiveness of a two-dose regimen in reducing fecal prevalence of *E. coli* O157:H7 in high shedding cattle reared in a commercial feedlot in the summer on a finishing diet with 25% distiller's grains.

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**Pre-harvest Agreements**

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.

**(5) Bacterial Extract Vaccines**

Application: Econiche™ is a bacterial extract vaccine. To make the vaccine, the bacteria are grown, and key proteins that cause the bacteria to attach to the intestines of cattle are extracted. Vaccinated cattle produce antibodies that affect the attachment proteins in the bacteria, preventing the bacteria from attaching and reproducing.

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. In

December 2011, the Australian Quarantine and Inspection Service granted an import permit for the vaccine, a required first step in gaining full approval of the vaccine. In August 2012, the United Kingdom approved the importation of the vaccine to be used under conditions of a Special Treatment Certificate. Econiche™ is not licensed in the United States.

Econiche™ is a three-dose vaccine, but it has also been tested as a two-dose vaccine. U.S. feedlot practices do not easily accommodate a three-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%.

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## V. CONCLUSION

### Multi-hurdle Approach

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Food producers recognize that applying pre-harvest interventions with post harvest technologies for a “multi-hurdle” approach is the most effective way to minimize contamination of foods.

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[http://www.ars.usda.gov/research/publications/publications.htm?seq\\_no\\_115=227290](http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=227290)

Several strategies to reduce fecal shedding of STEC in beef cattle production have been discussed above. Other resources are also available including the beef industry’s guidance on production best practices (<http://www.bifsc.org/CMDocs/BIFSCO/Production%20Best%20Practices.pdf>) and cattle ecology and management options (<http://afajournal.com/articles/current-and-near-market-intervention-strategies-for-reducing-shiga-toxin-producing-escherichia-coli-stec-shedding-in-cattle/>) produced in collaboration with ARS and academia. It is generally recognized that a multi-hurdle approach involving application of preventive measures at both pre-harvest and post-harvest should be more effective at reducing the chance of contamination at harvest. The Agency encourages pre-harvest interventions as the first control steps in an integrated food safety system.

FSIS acknowledges that several gaps exist in pre-harvest food safety research and knowledge. The Agency provides guidance and support to other government agencies that conduct research, academia, and industry to encourage them to conduct priority food safety research. FSIS research priorities are posted on FSIS' website at <http://www.fsis.usda.gov/wps/portal/fsis/topics/science/food-safety-research-priorities>. With appropriate data, further assessments and modeling of the relationships among fecal prevalence and concentration, hide contamination, and subsequent carcass contamination can be made to further define risks and benefits of STEC interventions on contamination of beef.

“The purpose of the pre-harvest hurdle would simply be to control the prevalence to such a level that the in-plant hurdles would not be overwhelmed.”

[Dr. Guy Loneragan,](#)  
[Texas Tech Professor,](#)  
[&The E. coli Issue](#)

## Appendix 1: What are Shiga Toxin-Producing *Escherichia coli* (STEC)?

STECs are associated with cattle and disease in humans. *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. Several strains of *E. coli* have evolved from being mildly pathogenic in humans to being highly pathogenic and capable of causing death when they infect humans. Symptoms of infection vary from person to person but often involve severe gastroenteritis, bloody diarrhea, vomiting, and mild fever if present. STEC can cause hemorrhagic colitis and hemolytic uremic syndrome in humans, especially in children, the elderly, and those in weakened immune states. Hemorrhagic colitis and hemolytic uremic syndrome are more commonly associated with infections resulting from *E. coli* O157:H7.

Since 1994 when FSIS declared *E. coli* O157:H7 to be an adulterant in ground beef, it has been the *E. coli* strain of primary interest to FSIS because of its (1) presence on the hide and in the gut of cattle presented for slaughter; (2) its presence as a contaminant in raw beef component used to make ground beef; and (3) low infectious dose capable of causing severe human disease and death associated with consumption of undercooked non-intact beef products such as ground beef, which is the most frequently implicated source of *E. coli* O157:H7 outbreaks in the United States. However, the Centers for Disease Control and Prevention identified six additional strains of STEC (O26, O45, O103, O111, O121, and O145) that are pathogenic. These strains have been found on the hide, in the gut, and in the feces of cattle at levels comparable to those for *E. coli* O157:H7. In September 2011, FSIS declared these six additional strains as adulterants in beef.

Since 1994, the beef industry has invested time, effort, and research on post-harvest interventions, focusing its 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 using sanitary practices during fabrication of trim and ground beef products to minimize cross contamination 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 – as well as non-O157 STEC – load on cattle entering the slaughter establishments is reduced, there would be a corresponding reduction in *E. coli* O157:H7 on carcasses and in ground beef.

**NOTE:** In addition to STEC, cattle are reservoirs of several food borne pathogens including *Campylobacter* spp., *Cryptosporidium* spp., *Listeria* spp. and *Salmonella* and of several emerging human diseases, such as *Helicobacterium pylori* and *Mycobacterium avium* subspecies *paratuberculosis*.

## **Appendix 2: Ecology and Epidemiology of *E. coli* O157:H7**

### **Distribution:**

1. The bacteria are found sporadically in the gut of individual animals but are not associated with clinical disease in animals;
2. Widespread in animals and commonly found in cattle;
3. High numbers of these bacteria are found in the colon and rectum of cattle
4. Survives in many different environments remaining viable in water, soil, and manure for several months; and
5. Can be found in a variety of species including humans.

### **Prevalence (percentage of the population affected):**

1. Higher during warm months;
2. Higher in calves than mature cattle; and
3. Higher prevalence in animals after gut bacteria have been affected by feed changes, antimicrobial dosing, or transportation stress.

**Appendix 3: Summary Table of Pre-harvest Management Controls and Intervention Options for Control of *E. coli* O157:H7 Shedding in Cattle**

<b>A. Water and Feed</b>	
<b>Treatment</b>	<b>Application</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 before 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 the effect of forage diets on fecal shedding of <i>E. coli</i> O157:H7 is inconclusive.
	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, but this may have detrimental effects on performance. Some studies have shown an increase in shedding in cattle fed poor quality forage.
<b>B. Water and Feed Additives</b>	
<b>Treatment</b>	<b>Application</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. Development of antibiotic resistance to some antibiotics may have a negative impact on human health. Producer compliance with withdrawal times is required to prevent antibiotic residues in

	cattle presented for slaughter.
<b>2. Probiotics</b>	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 correctly to be effective.
<b>3. Colicin-producing <i>E. coli</i> strains</b>	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. However, colicins are not easily produced and are expensive.
<b>4. Seaweed Extract (Tasco – 14)</b>	When used as a feed supplement for two weeks before slaughter, it results in fewer naturally occurring <i>E. coli</i> O157:H7 in the feces and on the hides of cattle. However, some researchers indicate that data are insufficient to recommend that it can be used alone to control STEC.
<b>5. Ractopamine</b>	Preliminary studies have demonstrated a decrease in fecal shedding of <i>E. coli</i> O157:H7 and <i>Salmonella</i> in cattle. This is an FDA approved feed supplement for use to improve cattle quality and performance. Currently not FDA approved for reducing fecal shedding.
<b>C. Live Animal Treatments</b>	
<b>Treatment</b>	<b>Application</b>
<b>1. Bacteriophage</b>	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. As recently as April 2012, FSIS issued a letter of no objection for use of a Shiga toxin-producing <i>E. coli</i> targeted bacteriophage cocktail effective for <i>E. coli</i> serogroups O157, 026, 045, 0103, and 0145 for use on the hides of cattle within lairage or holding pens, restraining areas, stunning areas, and stations immediately before hide removal.
<b>2. Competitive Exclusion (CE)</b>	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.
<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>D. Management Practices and Transportation</b>	
<b>Treatment</b>	<b>Application</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 eliminates 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.