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Risk assessment of intervention strategies for fallen carcasses in beef slaughter establishments

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ABSTRACT

In the slaughter establishment, cattle carcasses move along the line attached to a slaughter chain. Cattle carcasses fall off the slaughter chain infrequently, but such an event results in carcasses potentially contaminated with bacteria that exist on floors and equipment. Microbes in the feces and ingesta of slaughtered livestock as well as microbes on the hide surfaces of those livestock contaminate the slaughter environment. This environment often will include important foodborne pathogens, such as *Escherichia coli* O157:H7. This analysis uses a risk assessment modeling approach to assess the potential public health effects of standardizing treatments for carcasses that fall off the slaughter chain at dehiding. This assessment examines combinations of six intervention options: 1) water rinse, 2) organic acid rinse, 3) trim, 4) organic acid rinse and trim, 5) carcass trimming and cook, 6) condemn the carcass. Potential improvement in public health results from progressive removal of the least effective of these intervention options. The results of this analysis indicate that the number of annual human *E. coli* O157:H7 illnesses avoided varies based on intervention type—organic acid rinsing (281), carcass trimming (787), organic acid rinsing plus trimming (1533), trimming plus cooking (1539), and carcass condemnation (1520). The model suggests that the numbers of illnesses prevented are largest and similar when either the organic acid plus trim, trim plus cook, or condemn interventions are set as the minimum. This conclusion was robust to sensitivity analysis of various uncertainties in the model. Interestingly, it was found that a universal condemnation of fallen cattle was not a necessary intervention. Although it was assumed that most large slaughter establishments currently implement a trimming plus cooking intervention for all fallen carcasses, the model suggests there is little difference among the three best interventions.

1. Introduction

During the slaughter process, cattle carcasses are shackled by the rear legs and hung from a ceiling rail. Carcasses are intended to remain connected to this overhead rail throughout the slaughter process. At the end of this process, carcasses have been split longitudinally and are moved into a chilling room to cool prior to fabrication of the carcass into various beef products.

Carcasses suspended from an overhead rail can; 1) move through the various slaughter processes rapidly, 2) be kept separate from other carcasses, 3) afford ready access of slaughter personnel, and 4) drain fluids efficiently. Hide removal occurs relatively early in the slaughter process and is the first opportunity for microbial pathogens to contaminate the underlying tissues.

Hide removal is completed in two phases. First, the hide is detached in the mid-back region, a metal bar is inserted through this region, and the hide lifted to detach it from the caudal two-thirds of the carcass. Following this phase, the hide is hanging over the head and attached across the cranial one-third of the back, as well as the neck, head, and forelimbs. The second phase uses a hydraulic system, and two conveyer belts running in opposite directions, to catch the loose end of the hide and pull it off the remainder of the carcass. Typically, the direction of the pull is toward the head and away from the attachments of the carcass to the rail.

Given the force of the pulling in the second phase, there is a chance that a carcass may be pulled off the rail. Although commercial slaughter establishments are engineered to keep carcasses suspended on the rail while dehiding occurs, the process can fail infrequently. Factors that increase the likelihood of a fallen carcass during dehiding include; presence of horn stumps, ineffective hooks, broken tendons, fast line speeds, and oversized carcasses.

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The U.S. Department of Agriculture, Food Safety and Inspection Services (FSIS) is responsible for monitoring the sanitation and hygiene of slaughter establishments. The requirement for FSIS regulated products that fall on the floor is that the product "…shall be cleaned (including trimming if necessary) or otherwise handled in a manner approved by the inspector to assure that it will not be adulterated or misbranded…" (9CFR Chapter 3(a) 318.2). FSIS regulations also address corrective actions, including reconditioning of product, in 9CFR Chapter 3(e) 416.15. Nevertheless, it is the responsibility of each slaughter establishment to develop its own standard operating procedure for carcasses that contact the floor.

A carcass that falls from the rail becomes substantially contaminated with bacteria that exist on floors and equipment in the slaughter establishment environment. Microbes in the feces and ingesta of slaughtered livestock, as well as on the hide surfaces of those livestock, contaminate the environment; foodborne pathogens, such as *Escherichia coli* O157:H7 and *Salmonella* spp. are of particular concern. If not effectively removed from fallen carcasses, these pathogens represent foodborne hazards for consumers of beef products.

There is limited information and analysis regarding the topic of carcasses that fall off the rail. A Best Practices for Beef Slaughter Guideline, developed by the National Meat Association, Southwest Meat Association, American Meat Institute, and the National Cattlemen's Beef Association asserts, "Procedures should be in-place to recondition any carcasses that fall…" (Harris & Savell, 2003). Nevertheless, this publication does not provide any further details or recommendations for managing or decontaminating these carcasses. Gill and Landers (2004) demonstrate that the numbers of bacteria at visibly contaminated sites were reduced when the sites were trimmed, such that highly contaminated carcasses that were trimmed gained similar or superior condition to those carcasses that were never contaminated.

Castillo, Lucia, Goodson, Savell, and Acuff (1998) report log reductions associated with various treatments to reduce bacteria of fecal origin on beef carcasses. The most commonly used bacterial reduction protocols involve water washes, organic acid rinses, trimming external surfaces, cooking contaminated product, or some combination of these options. Bacon et al. (2000) quantify the change in the microbial populations on beef carcasses as they move through different stages in the slaughter process.

Although carcasses that fall are exposed to substantial contamination, carcasses that remain on the rail also can be contaminated. This contamination may occur during dehiding or evisceration, as well as through contact with contaminated cutting utensils, contact surfaces, or nonpotable water (Smith, Fazil, & Lammerding, 2012). Bosilevac et al. (2009) estimated prevalence and levels of *E. coli* O157:H7 on hides and carcasses at two points in the slaughter process in U.S. slaughter establishments and found significant levels of contamination.

This analysis uses a risk assessment modeling approach to assess the potential public health effects of proposing standardized treatments for carcasses that fall off the slaughter chain at dehiding. Risk assessment is useful for examining the implications of different intervention strategies for reducing carcass contamination and public health risks (Cassin, Lammerding, Todd, Ross, & McColl, 1998; Ebel et al., 2004; Marks, Coleman, Lin, & Roberts, 1998; Smith et al., 2012). Combinations of six intervention options are assessed: 1) potable water rinse, 2) organic acid rinse, 3) trim, 4) organic acid rinse and trim, 5) trim and cook, and 6) condemn the carcass. The model output forecasts expected reductions in annual *E. coli* O157:H7 illnesses that might result from universal application of the most effective interventions.

2. Methods

This section explains the mathematical model developed to examine the potential reduction in human illnesses that might result from consistent performance of highly effective interventions to treat fallen carcasses. This analysis focuses on *E. coli* O157:H7 illnesses that result from consumption of beef products that are contaminated with this pathogen when carcasses fall off the rail at dehiding. After outlining the mathematical model, this section explains the data and assumptions used to inform this model.

2.1. Model development

The output generated by the risk model is the change in annual numbers of human *E. coli* O157:H7 illnesses (Δillnesses) that can be attributed to the different intervention-scenarios that are applied to carcasses that fall off the rail at dehiding. The output is generated using numbers informed by current research and industry standards. The criteria used to compare the output will be a simple ranking from lowest to highest illnesses avoided relative to a baseline (status quo) estimate.

Based on arguments outlined in Williams, Ebel, and Vose (2011a), we model the change in illnesses as proportional to the change in contamination levels on carcasses between a baseline set of interventions and an alternative (Alt) set of interventions. The model for estimating the change in illnesses is

$$\Delta\text{illnesses} = \left[\frac{E[Z_{\text{Alt}}] - E[Z_{\text{Base}}]}{E[Z_{\text{Base}}]}\right] \times \lambda_{\text{illnesses}}$$

where Z_{Base} is the post-dehiding contamination per carcass in the baseline scenario, Z_{Alt} is the post-dehiding contamination per carcass in an alternative scenario, and $\lambda_{\text{illnesses}}$ is the current annual rate of *E. coli* O157:H7 illnesses attributed to beef (i.e., the rate of illnesses that correspond to the baseline contamination level). The expectation operator ($E[.]$) indicates that we are using the expected value (i.e., mean) of the contamination distribution estimated for each scenario.

This simple approach to estimating the effect of alternative policies hinges on two main assumptions: 1) the doses of the pathogen consumed by humans are generally small and 2) the doses consumed depend on the levels of the pathogen on carcasses post-dehiding and the aggregation of effects associated with the processes of converting carcasses to servings (i.e., partitioning, mixing, amplification and attenuation), but these components are independent of one another.[1] The first assumption aligns with previous risk assessments that have estimated average exposure doses that are generally small (USDA, 2001). A small average dose generally suggests that exposures occur in the linear part of a typical dose–response function (Williams, Ebel, & Vose, 2011b).[2] Because specific pathogen levels per carcass are generally unknown to slaughter establishment personnel, wholesalers, retailers and consumers; it is reasonable to assume that carcasses and beef products are handled independently of the levels of pathogens on the products. Therefore, the second assumption also is reasonable.

We used a Monte Carlo simulation model to estimate Z_{Base} and Z_{Alt}. The baseline distribution of contamination levels among

[1] If D is the variable for dose per serving, Z is the variable describing post-dehiding contamination per carcass, Y describes the conversion processes such that $D = Z \times Y$; then the simplification only requires that Z and Y are independent so that $E[D] = E[Z] \times E[Y]$.

[2] As explained in Williams et al. (2011b), a dose smaller than 7000 CFU is generally in the "linear" part of the *E. coli* O157:H7 dose–response function. Furthermore, the FSIS risk assessment of *E. coli* O157:H7 estimates most exposures are well below this level (FSIS 2001).