

Chapter 3 Slaughter Module

Overview:

The probability of *E. coli* O157:H7 contamination and the level of contamination may vary for incoming live animals--perhaps attributable to different production practices on the farm, type of animal, type of feed, contaminated trucks, wet weather, travel time to the slaughterhouse--and these data are carried forward from the previous module. This chapter breaks the slaughter process into 5 steps and presents the evidence for *E. coli* O157:H7 contamination and/or decontamination at each step. While the hide and GI tract are likely to be significant sources of bacterial contamination for red meat carcasses, additional carcass contamination can arise from aerosols created during the slaughter and dressing process (Biss and Hathaway 1996b). Cross-contamination can also occur via contact with workers' hands or clothing, other carcasses, or contaminated equipment or environment. In addition to assessing the likelihood of contamination events, predicting microbial growth, survival and decline is central to modeling the slaughter process. Slaughterhouse operating procedures can either facilitate or control the likelihood of *E. coli* O157:H7 contamination and subsequent *E. coli* O157:H7 growth on beef carcasses or trim. Decontamination steps can significantly reduce the numbers of *E. coli* O157:H7 and other pathogens on the carcass or trim.

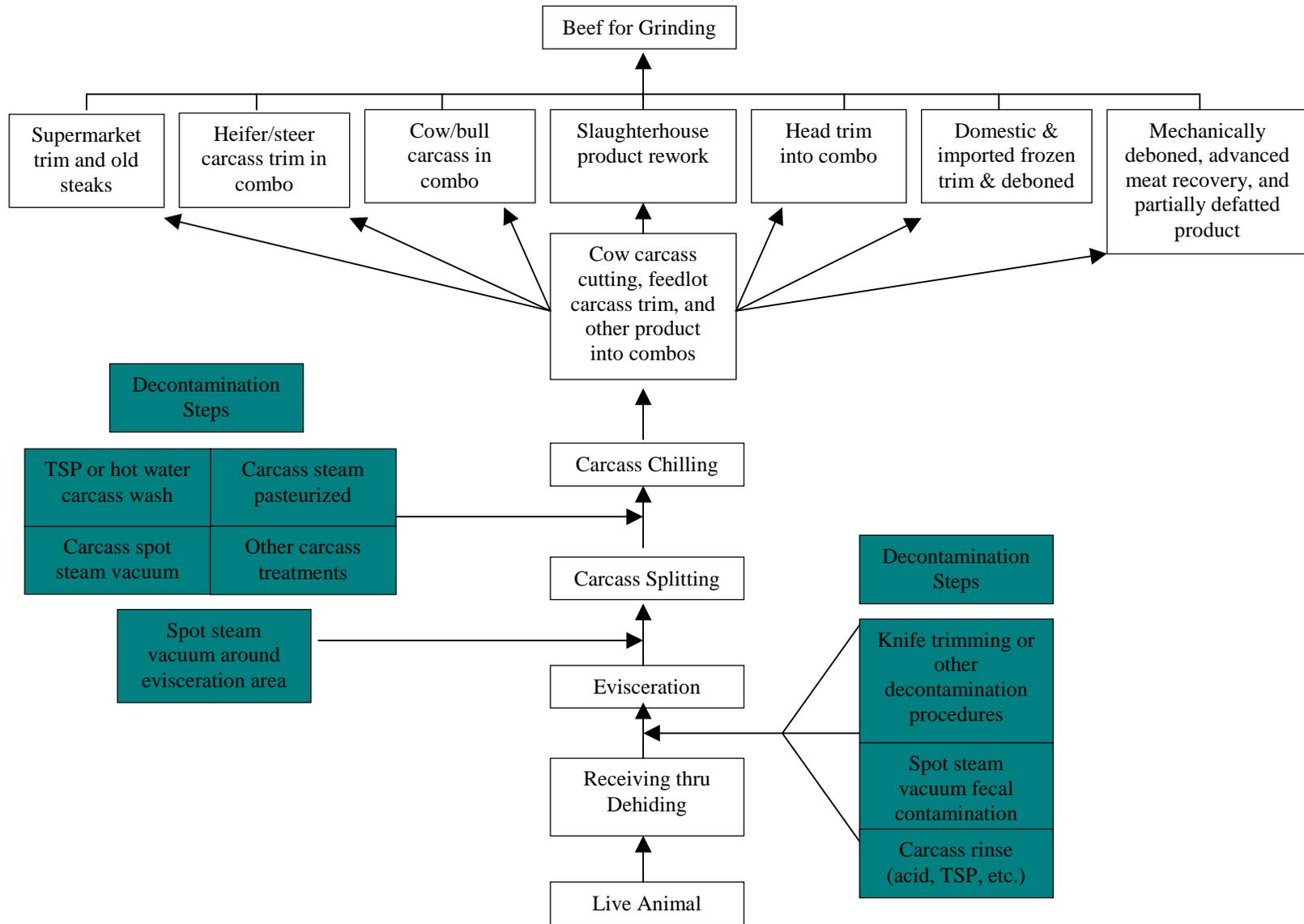
The nature of the evidence on the likelihood of *E. coli* O157:H7 reduction/survival/growth and cross-contamination is somewhat uneven. Few data are quantitative and specific to *E. coli* O157:H7. The quantitative microbial data acquired to date is limited to surrogate organisms (e.g., generic *E. coli*). Other pieces of data are entirely missing or based solely on expert opinion. Quantitative data from commercial plants are preferred as being most reflective of the "real world," since laboratory experiments may be performed with more care, by persons with more technical expertise, or at a slower line speed. If data are not available from United States operations, international data may be useful. In the absence of crucial pieces of data, expert opinion can be sought (Vose 1996, Kaplan 1992). Asking the experts to identify the evidence supporting their conclusions is thought to produce the highest caliber expert information.

Module Structure:

This chapter focuses on slaughter practices which increase/decrease the likelihood of *E. coli* O157:H7 contamination in beef. Which step(s) (or part of the step) is most risky varies with the pathogen. In the larger plants that produce most of the beef, there are usually the five following steps in slaughtering (Figure 3-1):

1

Figure 3.1 *E. coli* O157:H7 Slaughterhouse Module



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1 - Step 1: live animal receiving, stunning, shackling to an overhead rail, sticking, dehidng, and
2 application of decontamination measures, either individually or in combination (e.g., spot steam
3 vacuuming and knife trimming) to remove visible spots of fecal contamination.

4
5 - Step 2: removing the gastrointestinal tract and application of decontamination measures, either
6 individually or in combination (perhaps spot steam vacuuming before evisceration, knife
7 trimming afterwards to remove visible spots of fecal contamination, or other control procedures
8 such as carcass washes).

9
10 -Step 3: splitting the carcass and application of decontamination measures, either individually or
11 in combination (e.g., steam pasteurization of the whole carcass, or spot steam vacuuming of
12 selected areas plus carcass washes, or knife trimming and/or other decontamination steps).

13
14 - Step 4: chilling the carcass for 24 - 48 hours or more.

15
16 - Step 5: cutting the carcass into primals, subprimals, restaurant or consumer packages of beef;
17 placing the heifer/steer trim or deboned cow/bull meat into combo bins¹ for transport to a
18 grinding operation; adding advanced meat recovery beef, mechanically deboned beef, or beef
19 cheek/head meat to combos; processing and boxing partially defatted beef fatty tissue that may
20 be an ingredient in some beef patties.² These combos, boxes, and chubs then move onto the
21 grinding process that can take place in a variety of locations.

22
23 There are slaughter practices that deviate from this generic model. For example, bed skinning
24 and dressing is still practiced in some smaller plants. In some cases, beef may be transported off-
25 site from slaughterhouses to grinding/fabrication plants in the form of cut carcasses. Atypical
26 slaughter practices not discussed in this chapter may need to be considered if there are data
27 indicating that they represent a significant proportion of input to ground beef production, or if
28 there is evidence to suggest a lower or higher probability or variance for *E. coli* O157:H7
29 contamination than in the typical large slaughter plants.

30
31 Variables:

32
33 Input variables to the slaughter module will be the number and percent of cattle that have *E. coli*
34 O157:H7 in their intestinal tracts, on their hides, or both immediately prior to slaughter. For

¹ Combo bins or combos are large cardboard boxes bound with metal straps, lined with a large plastic bag, and placed on a wooden pallet for loading directly onto trucks or fork-lifting into a cooler. Combos vary in capacity up to 2,000 lbs. or more.

² In contrast to other mechanical separation processes that crush, grind, or pulverize meat and bone and employ sieves or screens to remove bone particles larger than 0.85 millimeters, advanced meat recovery systems that are intended to recover meat from bone without incorporating hard bone or bone-related components, including bone marrow and spinal cord. Partially defatted beef fatty tissue is a beef byproduct derived from the low temperature rendering (not exceeding 120° F) of fresh beef fatty tissue. The content of cheek meat (trimmed beef cheeks) in “chopped beef,” “ground beef,” “hamburger,” or “fabricated steak” is limited to 25%. Mechanically separated beef may constitute up to 20% of “beef patties,” which may also include partially defatted beef fatty tissue (9 CFR 319.15). For the current requirements for mechanically separated species, see 9 CFR 319.5. See 9 CFR 319.6 for limitations with respect to the use of mechanically separated species. Current regulations covering product derived from advanced meat recovery systems are found in 9 CFR 301.2(rr). Recently, however, FSIS proposed to amend these regulations (*Fed. Reg.*, Vol. 63, No. 70, pp. 17959-17966).

1 affected cattle, an additional input is the density of organisms per gram (for intestinal carriers) or
2 per square centimeter of surface area (for hide carriers). Other inputs will consist of the variable
3 and uncertain temperature and time profile during each step of the slaughter process, as well
4 other factors that may affect the rate of growth and decline of *E. coli* O157:H7. Because the
5 evidence and alternative models for predicting growth and decline of *E. coli* O157:H7 in beef is
6 relevant to both the slaughter and preparation modules, this discussion is presented in the
7 appendix on predictive microbiology. The output variable of the slaughter module will be the
8 number and percent of daily production (e.g., combos, boxes, or chubs) destined for the grinder
9 that are contaminated and the level of contamination with *E. coli* O157:H7. Variables will be
10 expressed as probability distributions to reflect uncertainty and/or variability in *E. coli* O157:H7
11 contamination, growth, survival, or reduction. The degree of separation in the model for different
12 types of cattle, plant size strata, processing types, decontamination treatments, etc. remains to be
13 determined.

14 15 Descriptions and Evidence - Step 1:

16
17 Cattle are received, stunned, shackled by one hoof and hung from a rail overhead, and stuck in
18 the throat with a knife to bleed out. All this action takes place in one room whose walls and floor
19 may become contaminated with pathogens on the hide, in blood, or in feces. Cattle are moved
20 down the overhead rail into the main floor of the slaughterhouse where cuts are made to free the
21 hide from the loose hoof in the hindquarters, the shackle is moved to the other hoof, the
22 remaining hooves are cut, the hide is loosened around the haunches, the second hoof is attached
23 to the rail, the udder and pizzle are removed, the bung is tied off to minimize fecal
24 contamination, the aitch bones in the hindquarters are split, the hide is loosened around the head,
25 and the hide is removed manually or attached to a hide puller which also skins the head, and the
26 head is removed for trimming in another location (Gracey and Collins 1992).

27 28 *The evidence for Step 1:*

29 30 RECEIVING/STUNNING/RAILING

- 31
32 - The production module will provide input data on the O157 status of live animals.
33 - No evidence has been acquired on the probability of cross-contamination from other cattle and
34 floors/walls, the effect of sanitation measures, or the probability of *E. coli* O157:H7 growth in
35 this area.
36 - The duration of this step would typically be very short, however, some proportion of carcasses
37 are railed-out for inspection.

38 39 STICKING

- 40 - A dirty knife (or a clean knife cutting through a dirty hide) can introduce bacteria into the blood
41 stream during sticking and bleeding and potentially contaminate the blood stream and deep
42 tissues (Labadie, Gouet, and Fourand 1977).
43 - *E. coli* injected into the bloodstream of guinea pigs shortly before death rapidly declined in 15
44 minutes and none were present after 60 minutes, indicating that the bactericidal activities of
45 blood and tissue fluids persist for at least one hour after death (Gill and Penney 1979).

DEHIDING

- Dehiding can contaminate the carcass in many ways: direct contact between a carcass and a hide contaminated with *E. coli* O157:H7, cross-contamination via a worker's mesh gloves/hands/clothing when cutting the hide opening, cross-contamination from the walls or other carcasses, or aerosols created as the hide is removed.

- The data in the literature are primarily for generic *E. coli*. How the available data relate to the probability and levels of contamination with *E. coli* O157:H7 is uncertain and warrants further comment and careful examination.

- 1/3 of calves with *E. coli* hide contamination ended up with carcass contamination (Howe, Linton and Osborne 1976). There is a low level of carcass coliform contamination of calves after hide removal, "leaving behind a relatively uncontaminated surface" (*Ibid.*, p. 39).

- On beef slaughter lines, Schnell *et al.* (1995) found *E. coli* counts of 1.29 mean log colony forming units (CFU)/cm²±0.78 after skinning. (Such data could be more usefully applied to the risk assessment if the raw data were obtained and fit to an appropriate distribution to characterize the variability in fecal contamination levels.)

- 95% value for carcass sites contaminated by direct fecal contact or contact with fecally contaminated hides; *E. coli* counts exceed log 2.00 CFU/cm² (Bell 1997).

- Carcass sites in contact with a "clean" hide occasionally had *E. coli* counts not exceeding log 2.00 CFU/cm² (Bell 1997).

- Location on carcass with positive *E. coli* counts: inside hind leg, hock, bung, outside hind leg, flank (descending levels) (Bell 1997).

- Aerosol contamination is an important source of "background" contamination of <2 logs on carcass (Bell, p. 299); airborne bacteria in a beef plant averaged 1.22 to 2.71 log CFU/100 liters of air (note, standard deviation is also given) (Rahkio and Korkeala 1997). Some plants minimize creation of aerosols in dehiding using air pressure and/or plant layouts that have an airflow pattern that moves air from the cleanest areas to the dirtiest.

- *E. coli* on hands of slaughterhouse workers during work averaged 5.05 logs CFU/cm² in calf plants and 3.01 logs in cattle plants (de Wit and Kamplmacher 1982); after opening cuts in the hide, beef slaughterhouse workers had 4.04 logs CFU/cm² (with a standard deviation of 0.67) on their hands (Bell 1997).

DECONTAMINATION TO REMOVE VISIBLE FECAL CONTAMINATION

- To remove surface contamination of blood, hair, dirt, and fecal matter containing pathogens, various combinations of decontamination processes are used in beef slaughter plants. In one scenario, knife trimming of visible fecal contamination can be used. Another option is to use two workers stationed at two heights and using a handheld, steam vacuum to removal visible contamination from the carcass that is less than 1" in diameter (larger spots require knife trimming). The evidence for decontamination measures is discussed under Step 3.

Descriptions and Evidence - Step 2:

The gastrointestinal (GI) tract is removed by carefully sawing open the brisket to avoid penetrating the rumen. The bung and the rest of the GI tract is carefully loosened from the carcass using a knife and removed along with the lungs, heart, and other organs. Step 2 could lead to carcass surface contamination, as the GI tract from positive cattle could rupture during the process and release *E. coli* O157:H7. The released bacteria could colonize the surface of the

1 carcass via direct contact between the GI tract and carcass or via indirect contact with
2 contaminated equipment, workers' hands or clothing, aerosols, and/or other carcasses.
3 Decontamination steps commonly include knife trimming around the bung area and spot steam
4 vacuuming of the evisceration area, either before or after evisceration. Carcass washes and other
5 decontamination procedures are used in some plants.

6
7 *The evidence for Step 2:* GI tract removal, rump trimming, and other possible decontamination
8 actions.

9 - The production module will provide data on the likelihood of gastrointestinal (GI) tract being
10 contaminated with *E. coli* O157:H7 and on the concentration of *E. coli* O157:H7 in GI positive
11 animals.

12 - No evidence on the time and temperature profile during Step 2 has been acquired. Although the
13 duration of this step would typically be very short, some proportion of carcasses may be diverted
14 from the main flow of the slaughter process and held for some period of time.

15 - No evidence regarding the relative frequency of rupture or puncture of the intestinal tract
16 during evisceration.

17 - "Evisceration can be carried out with minimal contamination of the carcass provided the
18 intestinal tract is not ruptured or punctured" (Bell 1997 - based on Nottingham, Penney, and
19 Harrison 1974 and Grau 1979).

20 - Data on the contribution of evisceration to microbial loads are minimal since samples are
21 seldom taken at that location. It is more common to sample after dehiding and after splitting, but
22 not directly after evisceration. Changes due to the combined effects of evisceration and splitting
23 and the associated decontamination procedures have been reported, but most changes are not
24 statistically significant for generic *E. coli* (Gill, McGinnis, and Badoni 1996a, Gill, Badoni, and
25 Jones 1996, Schnell *et al.* 1995). How the available data relate to the probability and levels of
26 contamination during evisceration with *E. coli* O157:H7 is uncertain and warrants further
27 comment and careful examination.

28
29 Descriptions and Evidence - Step 3:

30
31 The carcass is sawed in half, the tail is removed, other trimming is done, and excess fat is
32 trimmed off the carcass. The major risks for carcass contamination are cross-contamination via
33 machinery or hands. The major carcass decontamination steps occur here and include a variety of
34 industry practices using hot water washes, acid rinses, knife trimming, and steam pasteurization.

35
36 *The evidence for Step 3:*

37 - No evidence on the time and temperature profile during Step 3 has been acquired. Although the
38 duration of this step would typically be very short, some proportion of carcasses may be diverted
39 from the main flow of the slaughter process and held for some period of time.

40
41 - Several techniques can reduce *E. coli* O157:H7 levels, with 99.9% removal or more (3+ log
42 reduction) attainable by: steam pasteurization of whole carcasses, steam vacuuming after hide
43 removal of contaminated spots on the carcass (Table 3-1). When approved, irradiation could also
44 be an effective decontamination treatment (CAST 1996). Several decontamination treatments,
45 often in combination, can occur after splitting: trimming, washing (hot water and/or
46 antimicrobial), and/or steam pasteurization. In a recent study which is the most comprehensive

1 analysis of the decontamination procedures, Phebus *et al.* (1997) compared these treatments
2 alone and in combination (Phebus *et al.* 1997) (Table 3-1a).

3 4 Knife Trimming and Steam Vacuuming:

5 - Removal of visual specks of feces or ingesta (>1 inch) by trimming is required by the
6 USDA/FSIS (1995a). Steam vacuuming can replace trimming for specks of <1 inch.

7
8 - The effect of knife trimming has most often been determined on inoculated meat samples
9 and/or in laboratory settings. These studies do not mimic the trimming process in slaughter
10 plants, as the distribution of fecal material is often uniform, trained personnel conduct the
11 trimming, and the good aseptic trimming techniques are used. Trimming by these methods is
12 successful in decreasing microbial loads on carcasses, but should be used with caution in
13 determining the effect of trimming in slaughter plants (Dorsa 1997).

14 - Gill, McGinnis, and Badoni (1996b) found that the rump site is extensively decontaminated by
15 trimming away contaminated meat with a knife.

16
17 - Two in-plant studies determined that, for specks less than 1 inch, steam vacuuming reduced
18 aerobic bacteria by 0.82 and 0.72 log CFU/cm² more than trimming. The effects of steam
19 vacuuming are described below (Table 3-1) and could also be significant after carcass splitting.

20 - Steam vacuuming typically combines physical vacuum removal of bacteria and steam
21 decontamination. The system is passed over spots of the carcass exhibiting visual fecal
22 contamination. One study recorded the regrowth of *E. coli* O157:H7 up to 21 days of simulated
23 commercial storage after steam vacuuming (Dorsa 1997). After 2 days of storage at 5°C, counts
24 initially increased by 1.2 log CFU/cm², but after 21 days they were still 1.4 log CFU/cm² lower
25 than the control. Thus, long-term decontamination by steam vacuuming was exhibited.

26 27 Washing Treatments:

28 - Several washing treatments alone or in combination with steam pasteurization can be used to
29 decontaminate the carcass before it enters the chiller (Figure 3-1).

30 - Washing can decrease microbial loads anywhere from 0 to 5 log CFU/cm² depending on the
31 duration of the spray, the temperature of the solution, and whether or not organic acids, chlorine
32 and/or trisodium phosphate were used (reviewed in Dorsa 1997 and Delazari *et al.* 1998).

33 - An ambient temperature or warm water wash (35°C) reduces microbial loads by less than 1 log
34 CFU/cm² (Table 3-1).

35 - Data on the proportion of plants using each washing procedure has not been acquired. Absent
36 such data, performance data for least effective wash will be used tentatively for the model.

37 38 Steam Pasteurization:

39 - Steam pasteurization is a relatively new decontamination technique for sides of beef (Wilson
40 and Leising patent 1994). Surface water is removed by vertical blowers in a pressure chamber.
41 The water removal serves to prevent pools of residual water from protecting bacteria from the
42 steam. Steam is then applied for 5-15 seconds, followed by a cold water wash to cool the side
43 and return the “bloom,” or color, to the sides of beef. An increasing number of large plants are
44 using steam pasteurization chambers.

- The most relevant studies on the effect of steam pasteurization were conducted in commercial beef processing plants (Nutsch *et al.* 1997, Nutsch *et al.* 1998) using the commercial steam pasteurization chamber and naturally contaminated carcasses (Table 3-1d). In the study reported in 1997, *E. coli* levels were reduced from 0.6 log CFU/cm² to undetectable levels. A subsequent study by Nutsch *et al.* looked at the effect of steam pasteurization in commercial plants at five locations on the carcass (Nutsch *et al.* 1998). Studies using inoculated carcass cuts indicate an approximate 3.5 log reduction for *E. coli* O157:H7 (Phebus *et al.* 1997).

Table 3-1. Effectiveness of Carcass Decontamination Treatments for *E. coli* O157:H7,

a: Combined Impact of Several Treatments

Treatment(s)	Initial inoculum (log scale)	Mean reduction (log scale)
Knife trimming (overestimate of reduction)	5.14+/-0.12	3.10+/-0.49
Water wash 35°C	5.17+/-0.07	0.75+/-0.49
Spot steam vacuum + water wash	5.07+/-0.05	3.11+/-0.49
Steam pasteurization - 15 seconds	5.05+/-0.05	3.53+/-0.49
Spot steam vacuum + water wash + 2% lactic acid spray + steam pasteurization	5.20+/-0.05	4.65+/-0.53

Note: A one log reduction reduces pathogens by 90%, a two log reduction is 99%, and a three log reduction reduces pathogens by 99.9%.

Source of data: Phebus *et al.* 1997.

b: Effect of Steam Vacuuming on Microbial Loads

Study	Mean Log Reduction after Vacuuming (log CFU/cm ²)
Phebus et al. 1997	3.11 ± 0.49, <i>E. coli</i> O157:H7 (inoculated 5.1)
Dorsa, Cutter and Siragusa 1997b	2.1 ± 0.3, <i>E. coli</i> O157:H7 (inoculated 5.2)
Dorsa, Cutter, Siragusa 1996	5.5 ± 0.25, <i>E. coli</i> O157:H7 (inoculated 7.6)

c: Effect of Water Washing on Microbial Loads

Study	Mean Log Reduction after Washing (log CFU/cm ²)
Phebus et al. 1997 (inoculated with 5.17)	0.75 ± 0.49, <i>E. coli</i> O157:H7, carcass cuts
Hardin et al. 1995 (inoculated with 5)	1.0 ± 0.2, <i>E. coli</i> O157:H7, carcass cuts

d: Effect of Steam Pasteurization on Microbial Loads

Study	Mean Log Reduction after Steam Pasteurization (log CFU/cm ²)
Nutsch et al. 1998 (natural contamination)	undetectable for <i>E. coli</i> on 85% of carcasses
Nutsch et al. 1998 (natural contamination)	undetectable <i>E. coli</i>
Phebus et al. 1997 (inoculated, 5.0)	3.53 ± 0.49, <i>E. coli</i> O157:H7

1 Descriptions and Evidence - Step 4:

2
3 During the chilling step, the sides of beef are moved on a rail into a blast air chiller. For
4 carcasses contaminated with *E. coli* O157:H7 during previous steps of the slaughter process,
5 predicting microbial growth, survival and decline is central to modeling the chilling step.
6 However, the chilling step also involves the possibility of cross-contamination from other
7 carcasses. The risks of inadequate temperature control and cross-contamination are increased
8 when the chillers are overly full. Temperature and proximity to other carcasses varies within a
9 chiller for a given lot and between lots.

10
11 The evidence for Step 4:

12 - The application or adaptation of predictive microbiology models derived primarily from studies
13 of broth culture media inoculated at high initial densities to estimate microbial dynamics on the
14 exterior surface of carcasses (or intact cuts of muscle, as in Step 5) typically contaminated at low
15 initial densities is subject to uncertainty and warrants further comment and careful examination.
16 (See Predictive Microbiology Appendix.) Alternative approaches that are biologically plausible
17 and analytically feasible will be evaluated for inclusion in the risk assessment model.

18 - FSIS guidelines recommend chilling deep muscle (6 in.) to 50°F within 24 hours and 45°F
19 within 36 hours (NACMCF 1993) and that the surface be chilled to 10°C in 5 hours and to below
20 4.4°C in 24 hours (USDA-FSIS-1995b).

21 - A partial default probability distribution of the time carcasses spend in the chiller, the
22 temperature achieved at various sites on the carcass, and the likely *E. coli* proliferation is
23 available in an article by Gill and Bryant (1997). On average, they found *E. coli* reduced by 0.5
24 to 2 logs.

25 - Gill, Jones, and Tong (1991) examined a chilling facility operated on a 24 hour cycle where
26 sides of beef are sprayed with water. "When the sides were removed from the chillers, all the
27 sides from chiller No. 1 and all but three of the sides from chiller No. 2 had deep temperatures
28 above 10°C." The probability distribution of proliferation times for *E. coli* are presented.

29 - Both of the above studies were small, however, and may not reflect the full range of current
30 U.S. practices.

31 - Gill, Penney, and Nottingham (1976) found that "the death of the animal does not impair all
32 immunity mechanisms, which continue to rapidly kill any bacteria reaching the lymphatics." No
33 data have been acquired, however, on the potential mitigating effects of residual immune system
34 responses to the introduction of *E. coli* O157:H7.

35
36 - Dark, firm, dry (DFD) meat from animals with depleted glycogen reserves (due to prolonged
37 physical activity or stress) spoils more rapidly than normal meat (Newton and Gill 1978). It is
38 uncertain whether *E. coli* O157:H7 growth dynamics in DFD meat varies from that in normal
39 beef.

40
41 Descriptions and Evidence - Step 5:

42
43 The carcass is moved on the overhead rail from the chiller and cut into primals, subprimals, and
44 heifer/steer trim or deboned cow/bull meat is placed into combos prior to grinding. Grinding may
45 occur at the site of slaughter or off-site. In both cases, refrigerated storage time and temperature
46 will vary. In the case of off-site grinding, transportation time and temperature is also a factor.

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1 Some proportion of combos of cuts and/or trim may also contain comminuted product derived
2 from mechanical separation or advanced meat recovery, partially defatted beef fatty tissue,
3 and/or product rework that are introduced prior to the grinding operation. Operations vary among
4 plants and within plants over time. Major risk factors during Step 5 are temperature control and
5 cross-contamination from other pieces of meat, workers, or the conveyor belts.

6
7 *The evidence for Step 5:*

- 8 - Bacterial contamination has been observed for beef surfaces made by the trimming process
9 even with sterile utensils under experimental conditions (Jericho *et al.* 1996 - citing Hardin *et al.*
10 1995).
- 11 - No data have been acquired on the distribution of the size of pieces of beef or the varied
12 composition of beef placed in combos.
- 13 - No microbial count or *E. coli* O157:H7 prevalence data for combos have been acquired.
- 14 - The probability of contamination and the level of contamination with *E. coli* O157:H7 may
15 vary according to the type and mix of meat placed into the combos, e.g., trim from beef steaks
16 and roasts, whole cattle carcasses that are deboned, cheek meat, product rework, advanced meat
17 recovery product, mechanically separated beef, partially defatted tissue, etc. Some classes of
18 product are suspected of having generally high microbial counts, however, no microbial count
19 data have been acquired to enable a high degree of differentiation.
- 20 - Culled cows carcasses were found to be generally less contaminated with *E. coli* than the
21 trimmings obtained from the carcasses of feedlot steers (Gill, McGinnis, Rahn, and Houde
22 1996b).
- 23 - “A significant increase in fecal coliform count on meat cuts has been described after the boning
24 process of dairy cow carcasses” (Jericho *et al.* 1996 - citing Charlebois, Trudel, and Messier
25 1991).
- 26 - Gill and Jones (1992b) found *E. coli* growth in head meat ranging from 1-6 logs, with 1 and 2
27 log growth the most common.
- 28 - *E. coli* O157:H7 attaches similarly to beef muscle and adipose tissues (Cabedo, Sofos, Schmidt,
29 and Smith 1997), and thus the fat content is unlikely to explain variability in the probability or
30 level of contamination.
- 31 - Bruised tissues were microbiologically “no different” than unbruised cattle tissue, as long as
32 there was no deep penetration or “wound” associated with the bruise (Gill and Harrison 1982).
- 33 - Failing to reach optimum storage temperature before beef was loaded for transport was
34 identified by Gill and Jones (1992a) as a major factor contributing to poor storage performance.
- 35 - Canadian commercial chilling of combos with the addition of CO₂ snow was found to be
36 generally effective for containing proliferation of *E. coli* during storage and transport (Gill,
37 McGinnis, Rahn, and Houde 1996a), but “the temperatures achieved for some product were only
38 marginally within the chill temperature range.” The article provides a distribution of
39 temperatures of combos in five packing plants that can be used to estimate variability in chilling
40 temperatures.

41
42 **Conclusion:**

43
44 There are numerous data gaps and unresolved methodological issues. For each product type, the
45 output from the slaughter module will consist of distributions characterizing the uncertainty and
46 variability in the proportion of contaminated pieces of beef, the number of bacteria per

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1 contaminated piece, and the size of pieces of beef used for grinding. While some grinding of beef
2 is performed in slaughter plants, in this draft report, the grinding at all locations is discussed in
3 Chapter 4.
4

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