Risk Mitigation Strategies for Control of *E. coli* O157:H7 and STECs

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Foro Técnico Regional: *E. coli*: mitigación del riesgo en campo e industria

10 de diciembre de 2013, Montevideo, Uruguay

Risk Mitigation Strategies: *E. coli* O157:H7 and STECs

- Approaches to food safety
- Sources of contamination
- Antimicrobial Interventions
  - Hide interventions
  - Carcass interventions
  - Post chill intervention
- Ranking of risk mitigation strategies
- Conclusions

Timeline - New & Innovative Interventions

- 1993 *E. coli* O157:H7 Pacific Northwest
    - Knife trimming and water washing
- 2009 – Multiple meat processing interventions
    - Sequential
    - Hurdle Technologies
    - Primary and Secondary
    - At all phases of meat processing

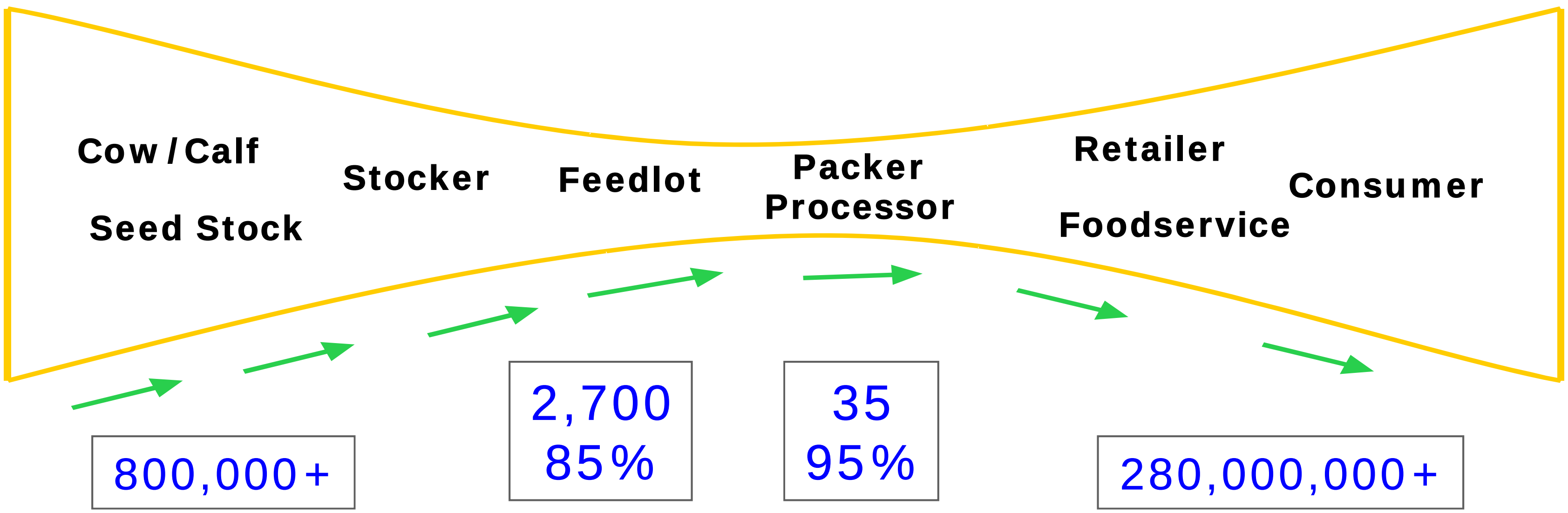
FSIS New Technology Information Table

- http://www.fsis.usda.gov/regulations_&_policies/New_Technology_Table_Feb_06/index.asp
- 37/52 filings (table shows listings for last 12 months) were related to poultry processing
- 12/52 associated with beef processing
  - BPI – Use of ammonium hydroxide on carcasses and boneless beef trimmings; anhydrous ammonia on ground beef
  - LA (up to 5%) on hot beef carcasses, beef subprimals and trimmings, heads and tongues
  - OmniLytics – *E. coli* O157:H7 and *Salmonella* phage sprays to live pre-slaughter cattle hides
  - Cargill – NaOH as hide-on carcass wash (post-exsanguination)
  - Tyson – 2.5% citric acid for head/offal wash
  - Elmhurst Research – Water under pressure in special vessel to kill pathogens in food
  - Agriprocessors – Low-pressure 20 ppm Na hypochlorite spray on beef primal cuts after Koshering

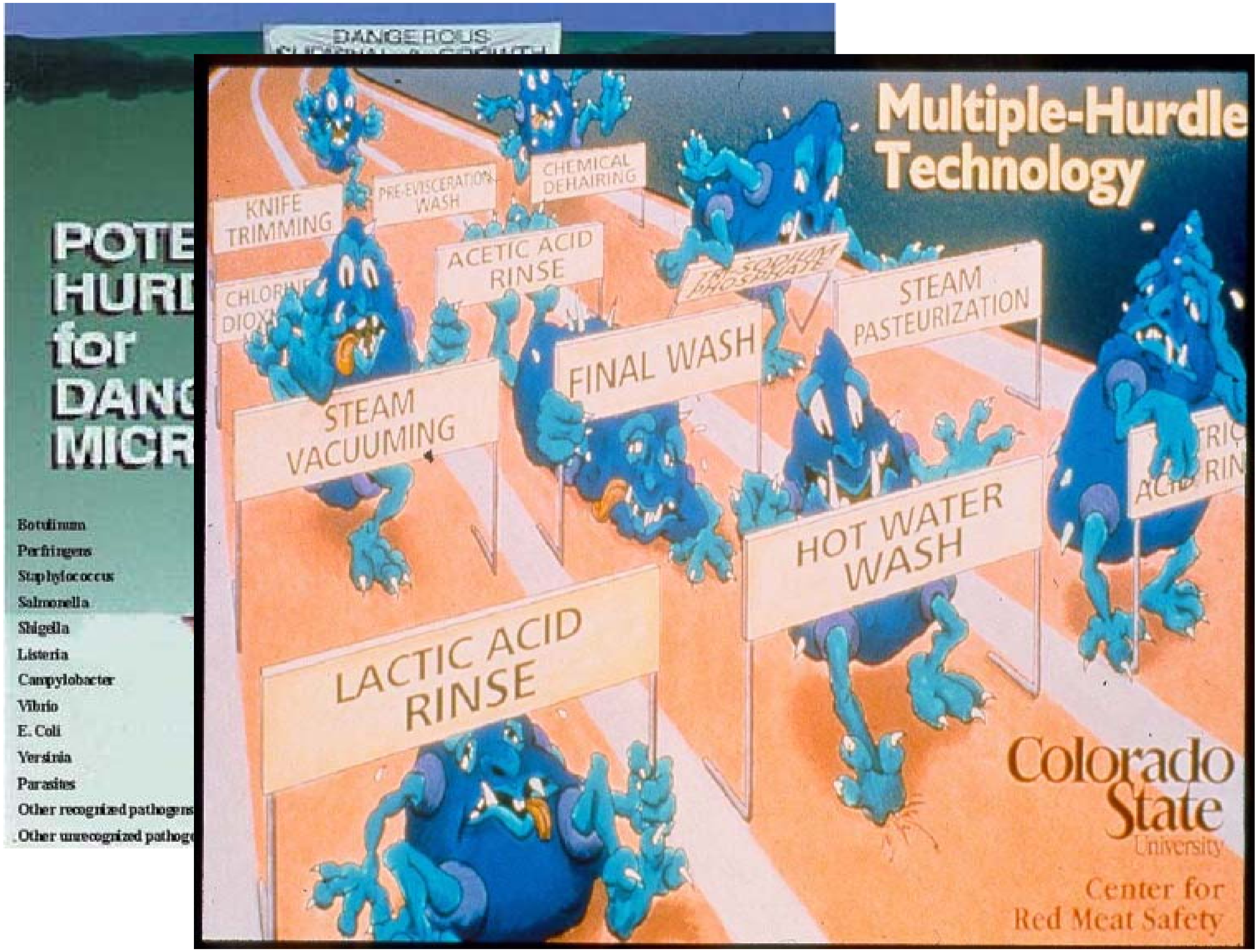
Today's Meat Safety Approach

- Integrated food safety concepts and validated technologies incorporated into a HACCP structure
- Based on science (hopefully)
  - systematic and verifiable process control
  - microbial kill step(s) -- pasteurization
  - secondary barriers to prevent microbial proliferation
  - sanitation and GMP pre-requisites
- Performance-based regulatory process
- Focused at the processor level, but with growing emphasis at the agricultural production and consumer levels

Strategies to Control *E. coli* O157:H7



Meat Production Continuum

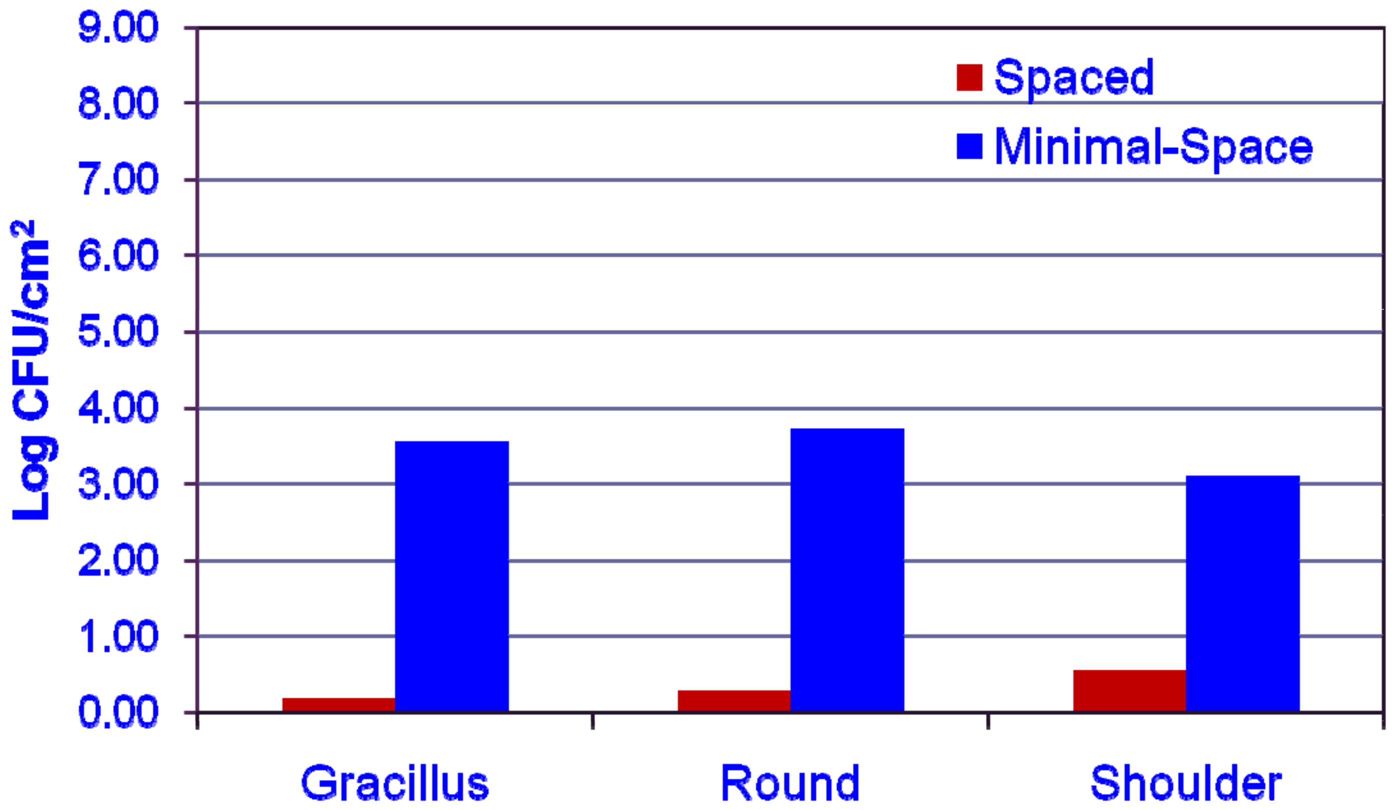

Botulinum
Perfringens
Staphylococcus
Salmonella
Shigella
Listeria
Campylobacter
Vibrio
E. Coli
Yersinia
Parasites
Other recognized pathogens
Multiple-Hurdle Technology
KNIFE TRIMMING
PRE-EVISCERATION WASH
CHEMICAL DEHAIRING
ACETIC ACID RINSE
STEAM PASTEURIZATION
FINAL WASH
STEAM VACUUMING
HOT WATER WASH
LACTIC ACID RINSE
Colorado State University
Center for Red Meat Safety

Post-Harvest Food Safety Breakdowns

- Inadequate processing control
- Slow carcass chilling (carcass spacing in hotboxes/coolers)
- Ineffective/marginally effective carcass intervention treatment
- Lack of control in cooking/fermentation/drying protocols in RTE meats

Post-Harvest Food Safety Breakdowns

- Recontamination of thermally processed products (repackaging, slicing, casing removal)
- Inadequate chilling of raw meat materials and processed products
- Raw ingredient contamination (meat trimmings, LFTB, spices)
- Poorly designed and/or operated HACCP and sanitation programs



Phebus, Thippareddi - unpublished carcass spacing in hotbox study (ca. 1998)

"The primary responsibility for food safety lies with food manufacturers

–

not with producers, government inspectors, and not with consumers

--

although they play a very important role."

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Correlation of enterohemorrhagic *Escherichia coli* O157 prevalence in feces, hides, and carcasses of beef cattle during processing

Robert O. Elder, James E. Keen, Gregory R. Siragusa, Genevieve A. Barkocy-Gallagher, Mohammad Koohmaraie, and William W. Laegreid*

United States Meat Animal Research Center, United States Department of Agriculture, Agricultural Research Service, Clay Center, NE 68933

Communicated by Harley W. Moon, Iowa State University, Ames, IA, January 19, 2000 (received for review December 2, 1999)

PNAS | **March 28, 2000** | vol. 97 | no. 7 | **2999–3003**

Data Summary

	Fecal	Hide	Carcass		
			Preevisceration	Postevisceration	Postprocessing
Total samples	91/327	38/355	148/341	59/332	6/330
Percent positive	27.8 (23.0–33.0)	10.7 (7.7–14.4)	43.4 (38.1–48.8)	17.8 (13.8–22.3)	1.8 (0.7–3.9)
Lots sampled	21/29	11/29	26/30	17/30	5/30
Percent lots positive	72.4 (52.5–86.6)	37.9 (20.7–57.7)	86.7 (69.3–96.2)	56.7 (37.4–74.5)	16.7 (5.6–34.7)
Mean positive/lot, %	26.2 (15.9–36.5)	13.0 (3.5–22.5)	43.4 (31.5–55.3)	18.3 (10.3–26.3)	1.9 (0.2–3.7)
Range, %	0–100	0–89	0–100	0–78	0–22

Values are number of samples positive for EHEC O157/total samples taken and percent positive (95% confidence interval).

Nebraska Lincoln EXTENSION

Know how. Know **now.**

Prevalence – Fecal, Hide & Carcass

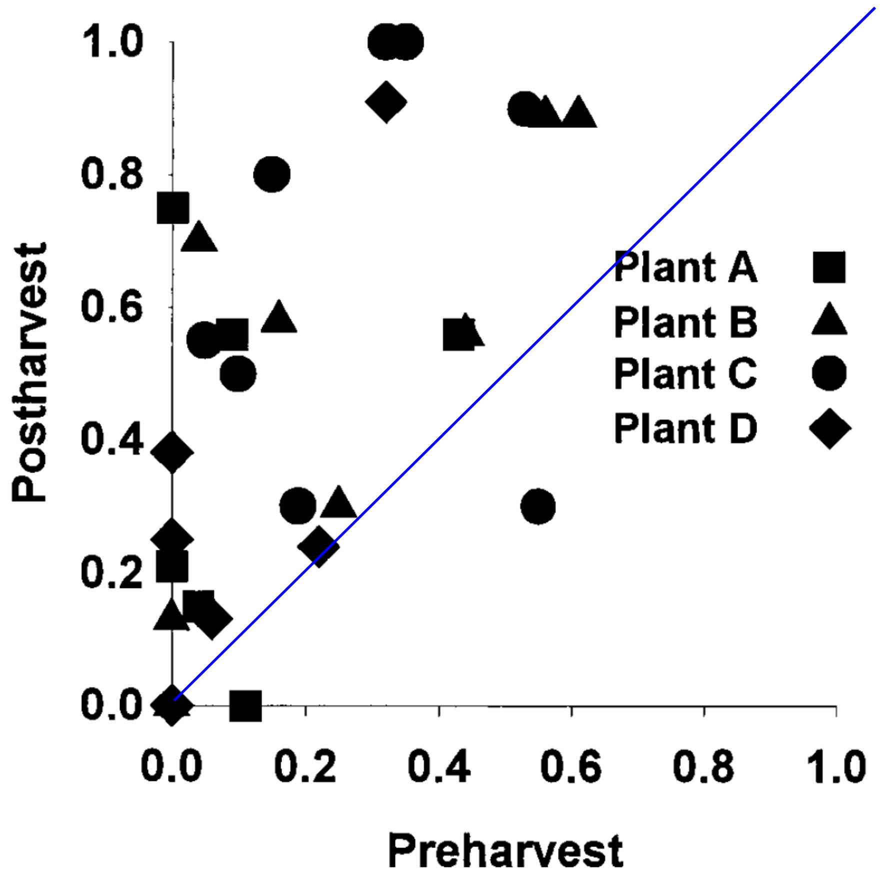


Fig. 1. Spearman rank correlation of EHEC O157 prevalence in all fecal and hide samples (preharvest) versus prevalence of carcasses positive on any sample (postharvest), by lot. Spearman rank correlation coefficient (r_s) = 0.58 (95% confidence interval 0.27–0.78), P = 0.001, n = 29.

Prevalence and Level of *Escherichia coli* O157:H7 in Feces and on Hides of Feedlot Steers Fed Diets with or without Wet Distillers Grains with Solubles†

J. E. WELLS,* S. D. SHACKELFORD, E. D. BERRY, N. KALCHAYANAND, M. N. GUERINI, V. H. VAREL, T. M. ARTHUR, J. M. BOSILEVAC, H. C. FREETLY, T. L. WHEELER, C. L. FERRELL, AND M. KOOHMARAIE‡

U.S. Department of Agriculture, Agricultural Research Station, U.S. Meat Animal Research Center, Clay Center, Nebraska 68933-0166, USA

MS 08-550: Received 31 October 2008/Accepted 6 March 2009

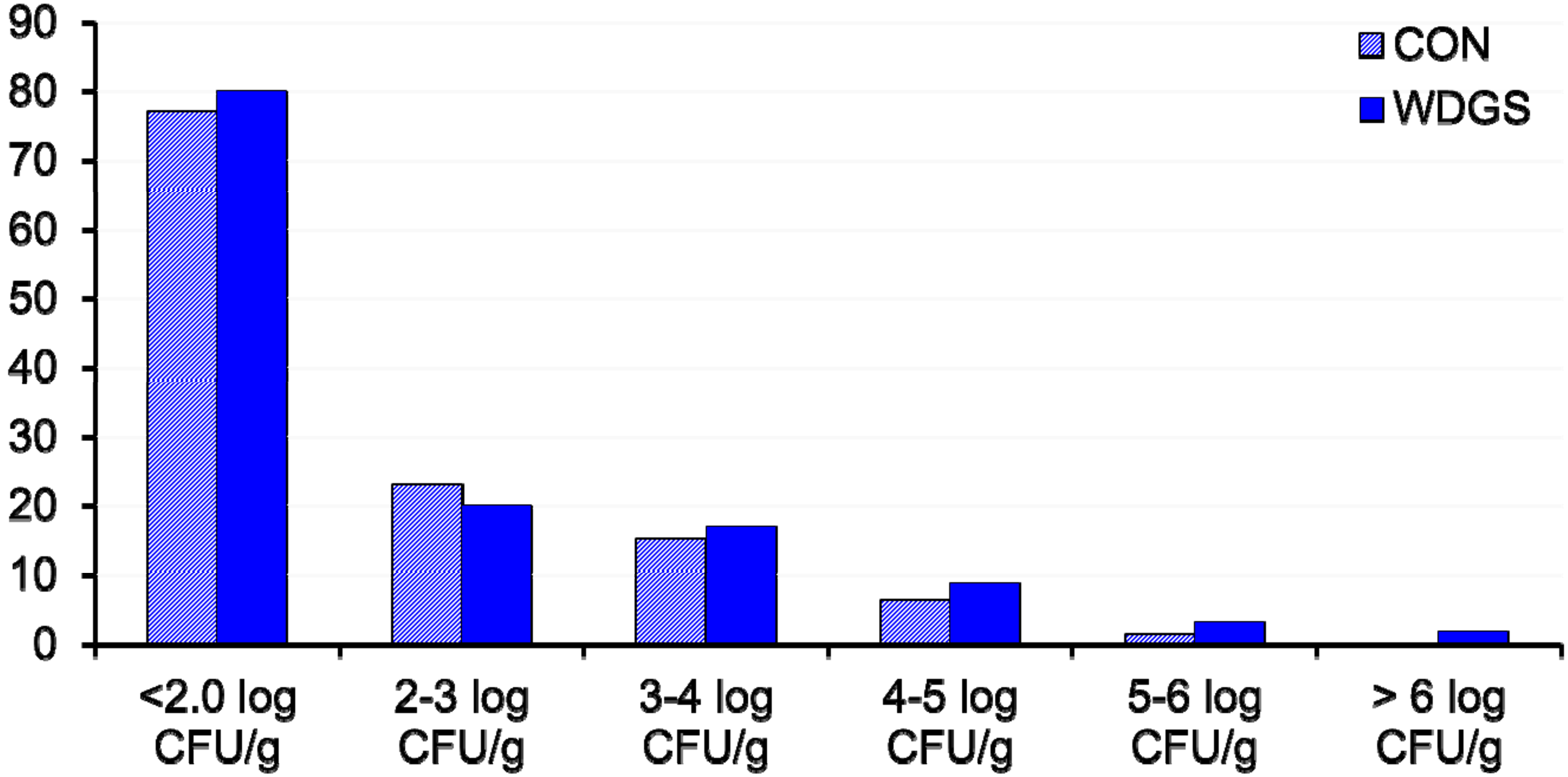
Journal of Food Protection, Vol. 72, No. 8, 2009, Pages 1624–1633

Distillers Grains - Hide Prevalence

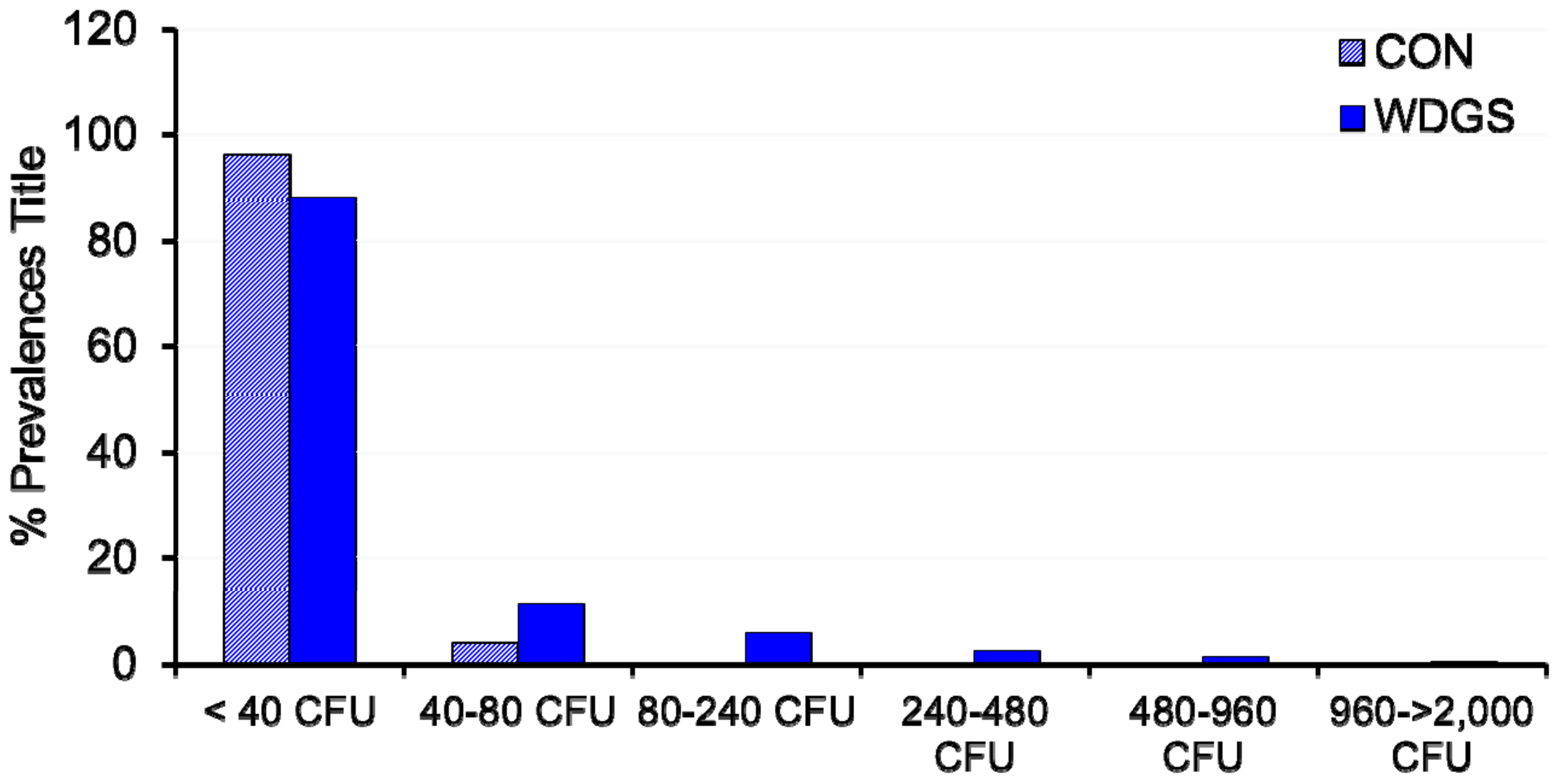
TABLE 2. *Percentage of samples with enumerable levels and prevalence of* Escherichia coli *O157:H7 in feces and on hides of cattle fed diets with and without WDGS*

Sample	Diet[a] CON	Diet[a] WDGS	SEM	*P* value
Feces, avg enumerable[b]				
Day 0	6.4	4.0	2.25	0.50
Growing phase	2.0	3.6	0.81	0.19
Finishing phase	0.1	2.7	0.36	0.0001
Feces, avg prevalence				
Day 0	6.7	5.0	2.39	0.63
Growing phase	8.8	17.8	2.05	0.009
Finishing phase	1.5	14.9	1.85	0.0001
Hides, avg enumerable[b]				
Day 0	9.8	11.6	6.61	0.88
Growing phase	1.7	7.4	2.67	0.16
Finishing phase	0.0	5.6	1.95	0.051
Hides, avg prevalence				
Day 0	55.3	54.5	6.61	0.86
Growing phase	42.8	58.5	6.04	0.09
Finishing phase	9.2	32.8	3.29	0.0001

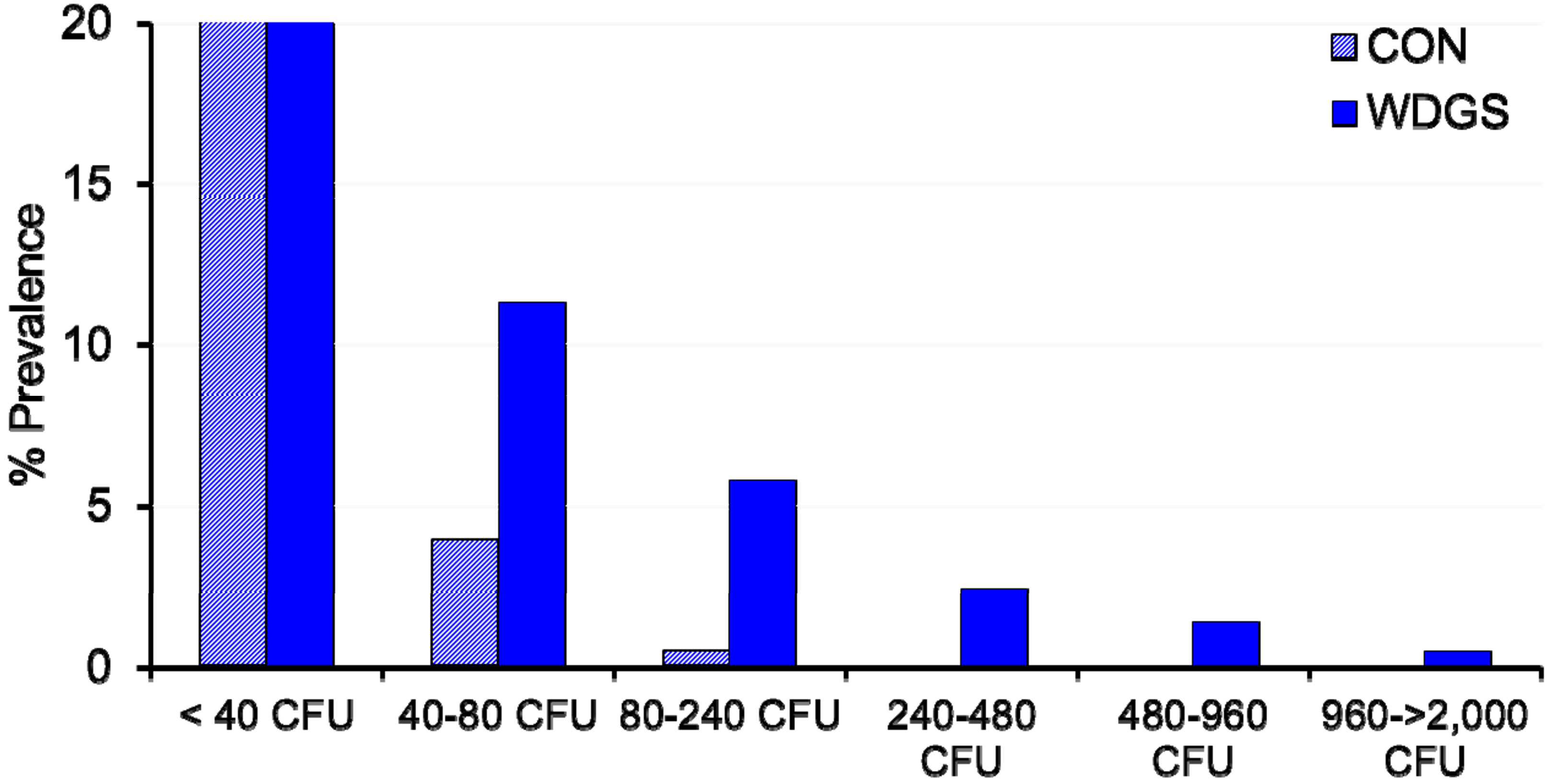
Fecal Prevalence & Numbers



Hide Prevalence & Numbers

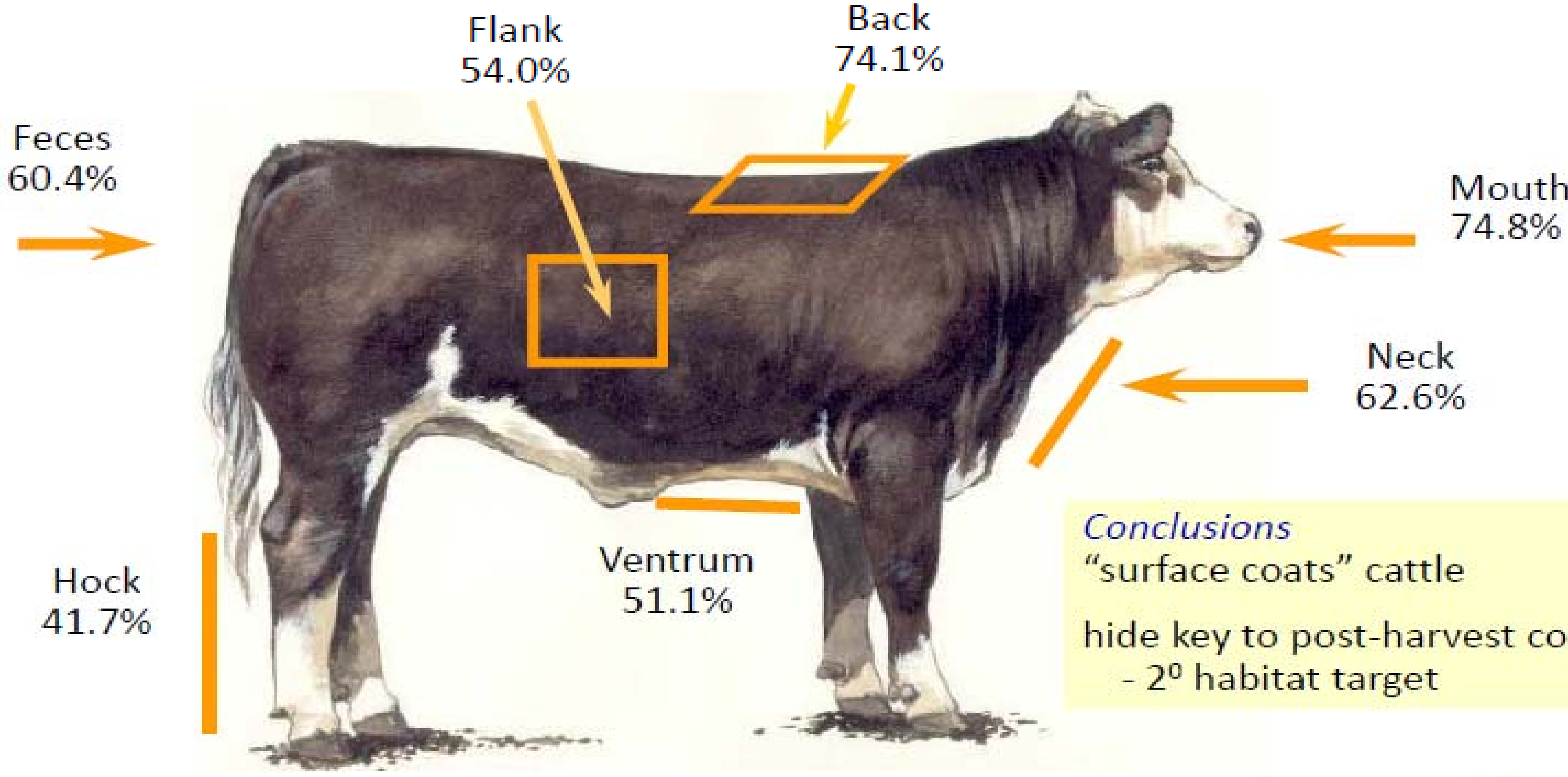


Hide Prevalence & Numbers



Habitats for STEC O157

% positive by site in 139 show list (slaughter-ready) cattle in 4 non-adjacent feedlot pens June 1999, NE



Conclusions
"surface coats" cattle

hide key to post-harvest control
- 2º habitat target

Keen & Elder, JAVMA, 2002

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Antimicrobial Interventions for Slaughter, Fabrication and Grinding

Antimicrobial Interventions

- Slaughter:
  - Chemical dehairing
  - Hide washes
  - Hot water rinses
  - Steam pasteurization
  - Steam vacuum
  - Chemical rinses
  - Lactoferrin

Antimicrobial Interventions

- Fabrication:
  - Organic acid rinses
  - Sanova
  - Ozone
  - Per-acetic acid
  - Lauric Arginate
  - Lactoferrin

Antimicrobial Interventions

- Trim for Grinding:
  - Organic acid rinses
  - Ozone
  - Per-acetic acid
  - ASC
  - Multiple hurdle technology
  - High Pressure Processing
- Ground Beef:
  - Irradiation

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Beef hide antimicrobial interventions as a means of reducing bacterial contamination

B.E. Baird, L.M. Lucia, G.R. Acuff, K.B. Harris, J.W. Savell *

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Received 13 September 2005; received in revised form 28 November 2005; accepted 28 November 2005

Meat Science 73 (2006) 245–248

Hide Intervention – Clipped Hair

Least squares means for aerobic plate counts (APCs), coliform, and *Escherichia coli* (*E. coli*) counts and log reductions on brisket area of clipped hides before and after treatment with antimicrobial agents

Indicator organism	Treatment	$Log_{10}CFU/100\text{-}cm^2$		
		Before	After	Reduction[a]
APC	1% CPC	8.2a	4.4c	3.8a
	2% L-lactic acid	7.5b	5.2b	2.3b
	3% Hydrogen peroxide	8.7a	6.5a	2.2b
	SEM[b]	0.22	0.21	0.28
Coliform	1% CPC	4.6b	1.3b	3.3a
	2% L-lactic acid	3.7c	1.1c	2.6a
	3% Hydrogen peroxide	5.2a	2.6a	2.6a
	SEM[b]	0.20	0.27	0.29
E. coli	1% CPC	4.3b	1.3a	3.0a
	2% L-lactic acid	3.2c	1.1b	2.1a
	3% Hydrogen peroxide	5.1a	2.1a	3.0a
	SEM[b]	0.24	0.29	0.33

Hide Intervention – Clipping

Least squares means for the interaction of clipping × antimicrobial agent on coliform reduction

Antimicrobial	$Log_{10}CFU/100\text{-}cm^2$ reduction[a]	
	Non-clipped	Clipped
Water	−0.1d	0.5d
Alcohol	0.2d	1.8c
1% CPC	5.3a	4.5ab
10% Povidone-iodine	2.4c	2.5c
2% L-Lactic acid	2.8c	4.1b
3% Hydrogen peroxide	2.2c	3.9bc
SEM[b]	0.43	0.43

Chemical Dehairing

- Uses sodium sulfide solution and subsequent neutralization with hydrogen peroxide
- Removes visible dirt and hair from the hide
- Improves microbiological quality of the carcasses and reduces *E. coli* O157:H7 prevalence

Effect of Chemical Dehairing on the Prevalence of *Escherichia coli* O157:H7 and the Levels of Aerobic Bacteria and *Enterobacteriaceae* on Carcasses in a Commercial Beef Processing Plant†

XIANGWU NOU,[1]* MILDRED RIVERA-BETANCOURT,[1] JOSEPH M. BOSILEVAC,[1] TOMMY L. WHEELER,[1] STEVEN D. SHACKELFORD,[1] BUCKY L. GWARTNEY,[2] JAMES O. REAGAN,[2] AND MOHAMMAD KOOHMARAIE[1]

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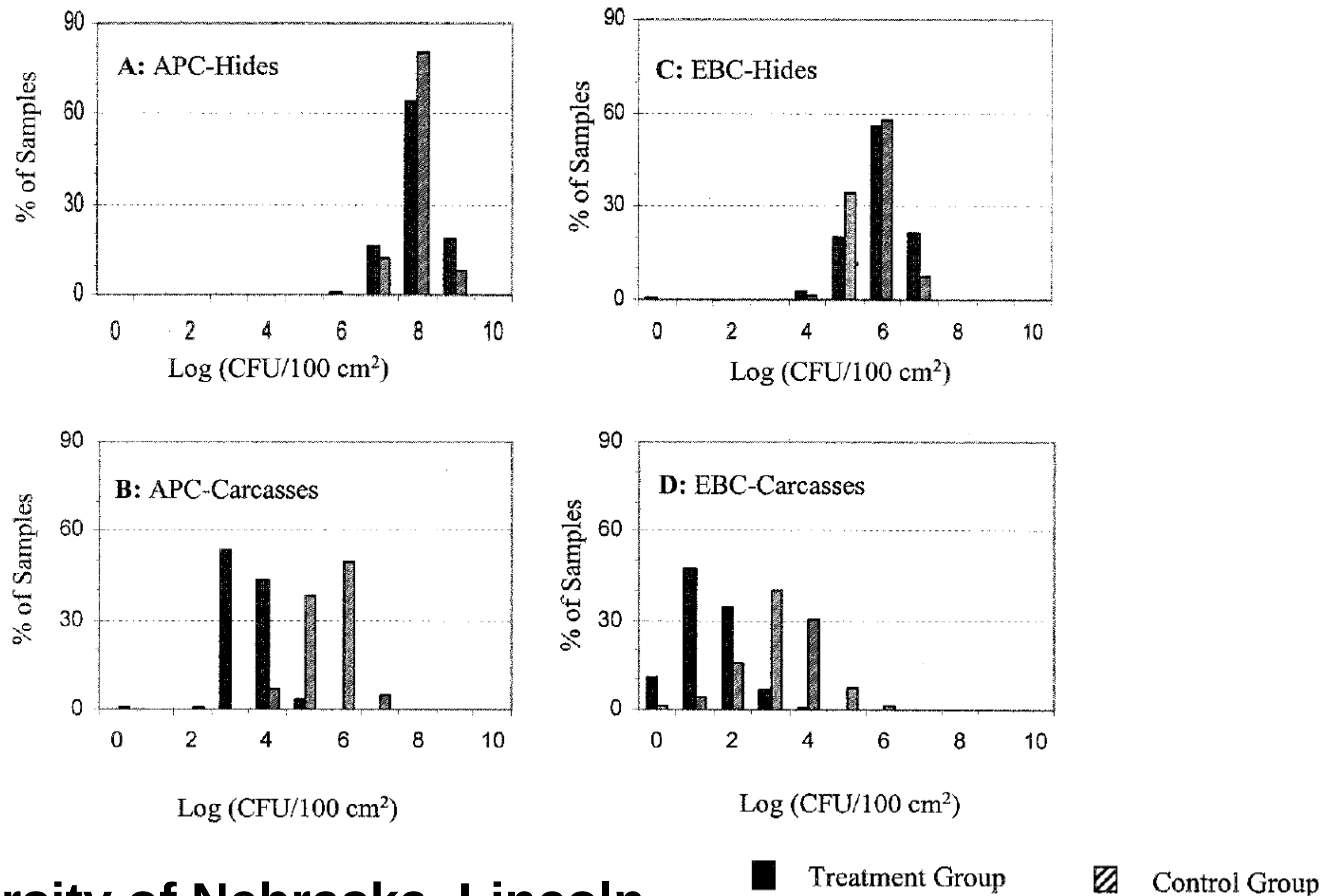
Journal of Food Protection, Vol. 66, No. 11, 2003, Pages 2005–2009

Chemical Dehairing – Hide Microbiological Status

Sample type	No. of samples	APC (log CFU/100 cm^2)	EBC (log CFU/100 cm^2)
Hides[b]			
Treatment group	240	8.1 A (0.5)	5.9 A (0.7)
Control group	240	8.0 A (0.4)	5.7 A (0.6)
Difference[c]		0.1	0.2
Carcasses[d]			
Treatment group	240	3.5 B (0.5)	1.4 B (0.7)
Control group	240	5.5 A (0.7)	3.2 A (1.0)
Difference		−2.0	−1.8

Chemical Dehairing – Hide Microbiological Status



Chemical Dehairing – Hide Microbiological Status

Sample type	No. of samples	*E. coli* O157:H7[a] No. positive	*E. coli* O157:H7[a] % positive
Hides[b]			
Treatment group	240	161	67 A
Control group	240	212	88 B
Carcasses[c]			
Treatment group	240	3	1 A
Control group	240	120	50 B

Review

Antibacterial activity of decontamination treatments for cattle hides and beef carcasses

Marianne Loretz, Roger Stephan, Claudio Zweifel*

Institute for Food Safety and Hygiene, Vetsuisse Faculty University of Zurich, 8057 Zurich, Switzerland

Food Control 22 (2011) 347–359

Hide Interventions - Individual

Agent/Microorganism	Reduction (log_{10} CFU)	Application	Contamination	Concentration	Temperature (°C)	Application time (min)	References
Water							
Aerobic bacteria	0.6–0.9/100 cm^2	Sponge	Artificial	–	20	NA[b]	Baird et al. (2006)
	0.1–0.5 cm^{-2}	Spraying	Natural	–	50	0.2	Small et al. (2005)
Coliforms	<0.5/100 cm^2	Sponge	Artificial	–	20	NA	Baird et al. (2006)
Escherichia coli	0.2/100 cm^2	Sponge	Artificial	–	20	NA	Baird et al. (2006)
Salmonella Typhimurium	0.7 cm^{-2}	Spraying	Artificial	–	24	0.1	Mies et al. (2004)
Steam							
Aerobic bacteria	3.0–4.0 cm^{-2}	Steam	Natural	–	80	0.1–0.3	McEvoy et al. (2003)
Lactic acid							
Aerobic bacteria	3.1 cm^{-2}	Spraying	Artificial	10%	55	0.1	Carlson, Geornaras, et al. (2008)
	2.7–4.1/100 cm^2	Sponge	Artificial	2%	55	NA	Baird et al. (2006)
	2.3/100 cm^2[a]	Sponge	Natural	2%	55	NA	Baird et al. (2006)
	2.1–2.3/100 cm^2	Spraying	Artificial	10%	55	0.1	Carlson, Geornaras, et al. (2008)
	1.6 cm^{-2}	Spraying	Artificial	10%	23	0.1	Carlson, Geornaras, et al. (2008)
Coliforms	2.8–4.1/100 cm^2	Sponge	Artificial	2%	55	NA	Baird et al. (2006)
	2.7/100 cm^2	Spraying	Natural	10%	55	0.1	Carlson, Geornaras, et al. (2008)
	2.6/100 cm^2[a]	Sponge	Natural	2%	55	NA	Baird et al. (2006)
Escherichia coli	3.3/100 cm^2	Sponge	Artificial	2%	55	NA	Baird et al. (2006)
	2.7/100 cm^2	Spraying	Natural	10%	55	0.1	Carlson, Geornaras, et al. (2008)
	2.1/100 cm^2[a]	Sponge	Natural	2%	55	NA	Baird et al. (2006)
Escherichia coli O157:H7	4.3 cm^{-2}	Spraying	Artificial	10%	55	0.1	Carlson, Geornaras, et al. (2008)
	2.9 cm^{-2}	Spraying	Artificial	10%	23	0.1	Carlson, Geornaras, et al. (2008)
Salmonella Typhimurium	1.3–5.1 cm^{-2}	Spraying	Artificial	2–6%	24	0.1	Mies et al. (2004)
Cetylpyridinium chloride							
Aerobic bacteria	4.1–4.6/100 cm^2	Sponge	Artificial	1%	20	NA	Baird et al. (2006)
	3.8/100 cm^2[a]	Sponge	Natural	1%	20	NA	Baird et al. (2006)
Coliforms	4.5–5.3/100 cm^2	Sponge	Artificial	1%	20	NA	Baird et al. (2006)
	3.3/100 cm^2[a]	Sponge	Natural	1%	20	NA	Baird et al. (2006)
E. coli	4.5/100 cm^2	Sponge	Artificial	1%	20	NA	Baird et al. (2006)
	3.0/100 cm^2[a]	Sponge	Natural	1%	20	NA	Baird et al. (2006)

Hide Interventions - Combinations

Combination/Microorganism	Reduction (log_{10} CFU)	Contamination	Temperature (°C)		Application time (min)		Referencess
			1st	2nd	1st	2nd	
Acetic acid and water							
Aerobic bacteria	0.9 cm^{-2}	Artificial	55	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
	0.5 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
Escherichia coli O157:H7	2.6 cm^{-2}	Artificial	55	20	0.5	0.5	Carlson, Ruby, et al. (2008)
	2.1 cm^{-2}	Artificial	55	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
	0.6 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
Salmonella spp.	2.0 cm^{-2}	Artificial	55	20	0.5	0.5	Carlson, Ruby, et al. (2008)
Lactic acid and water							
Aerobic bacteria	1.0 cm^{-2}	Artificial	55	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
	0.5 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
Escherichia coli O157:H7	3.4 cm^{-2}	Artificial	55	20	0.5	0.5	Carlson, Ruby, et al. (2008)
	1.8 cm^{-2}	Artificial	55	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
	0.8 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
Salmonella spp.	2.8 cm^{-2}	Artificial	55	20	0.5	0.5	Carlson, Ruby, et al. (2008)
Sodium hydroxide and water							
Aerobic bacteria	0.8 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al. (2008)
Coliforms	1.5/100 cm^{2}[a]	Natural	60	60	0.3	0.3	Bosilevac, Nou, et al. (2005)
Escherichia coli O157:H7	3.4 cm^{-2}	Artificial	23	20	0.5	0.5	Carlson, Ruby, et al. (2008)
	2.4 cm^{-2}	Artificial	23	23	0.1	0.1	Carlson, Geornaras, et al., (2008)
Salmonella spp.	2.6 cm^{-2}	Artificial	23	20	0.5	0.5	Carlson, Ruby, et al. (2008)
Sodium hydroxide and lactic acid							
Aerobic bacteria	2.0–2.4/100 cm^{2}	Natural	23	55	0.1	0.1	Carlson, Geornaras, et al. (2008)
Coliforms	2.1–2.9/100 cm^{2}	Natural	23	55	0.1	0.1	Carlson, Geornaras, et al. (2008)
Escherichia coli	2.3–3.0/100 cm^{2}	Natural	23	55	0.1	0.1	Carlson, Geornaras, et al. (2008)
Sodium hydroxide and chlorine							
Aerobic bacteria	2.1/100 cm^{2}[a]	Natural	65	35	0.2	NA[b]	Bosilevac, Nou, et al. (2005)
Enterobacteriaceae	3.4/100 cm^{2}[a]	Natural	65	35	0.2	NA	Bosilevac, Nou, et al. (2005)
Escherichia coli O157:H7	5.0 cm^{-2}	Artificial	23	NA	0.5	0.5	Carlson, Ruby, et al. (2008)
Salmonella spp.	4.4 cm^{-2}	Artificial	23	NA	0.5	0.5	Carlson, Ruby, et al. (2008)

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"Traditional" Interventions - Slaughter

- Thermal Carcass Pasteurization – Hot Water
  - Plant specific monitoring and validation/ verification
  - Manual versus automated
  - Reduce bacterial load by 1 to 3 $\log_{10}$ (Huffman, 2002)

Hot Water Rinses

- Hot water temperatures of >165 °F
- Processing water can be recycled
- Reduces general microbial load as well as *E. coli* O157:H7

Hot Water Rinses

	O. Round	Brisket	Flank
E. coli O157:H7			
Water Wash	2.7	1.7	1.9
WW + Hot Water	4.0	3.9	3.8
Coliforms			
Hides Before	1.6	1.4	2.4
Carcass After	3.8	3.4	4.0

@ Log CFU/cm^2 Reductions

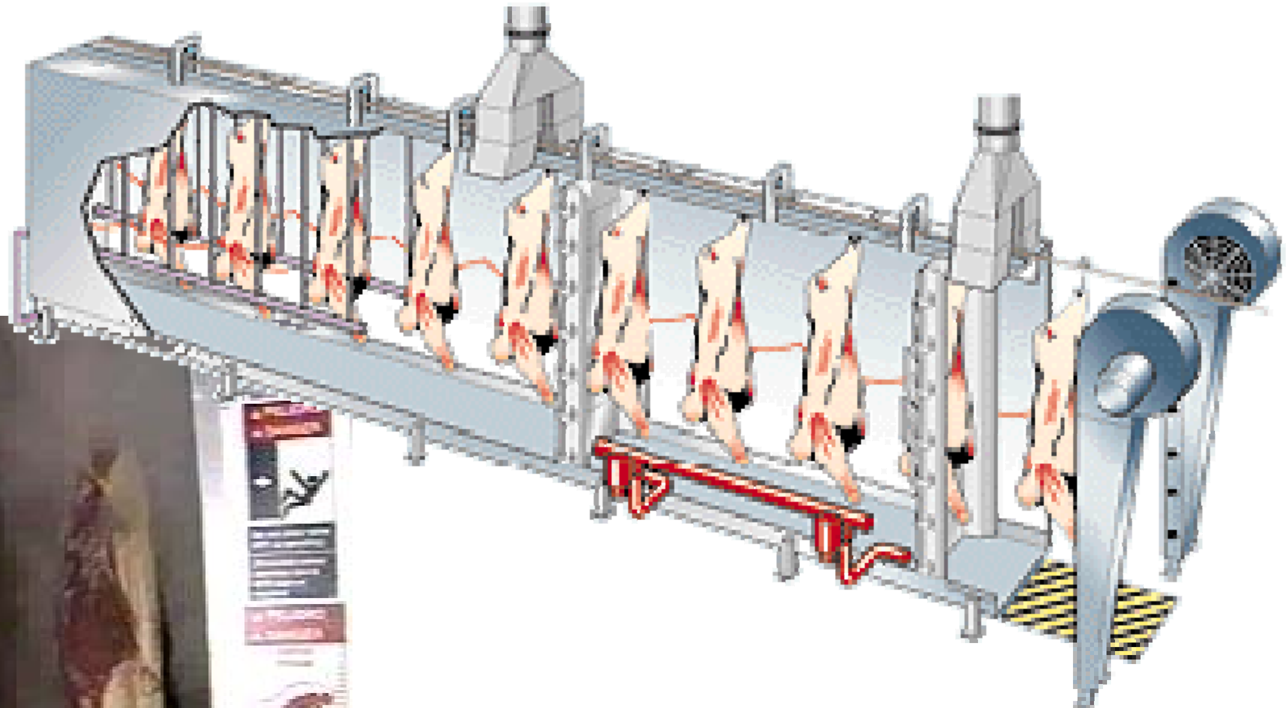
Castillo et al. 1998

Steam Pasteurization

- Uses condensing steam
- Immediate discoloration of the meat; but will bloom within 24 h
- Reduces general microbial load as well as *E. coli* O157:H7

"Traditional" Interventions - Slaughter

- Thermal Carcass Pasteurization – Steam Pasteurization



Steam Pasteurization

	Brisket*
E. coli O157:H7	
Water Wash	0.75
Steam Pasteurization	3.53
Coliforms	
Steam Pasteurization	1.25

@ Log CFU/cm^2 Reductions

Nutsch et al. 1998

Steam Vacuum

- Utilizes either hot water or steam, subsequently will vacuum the extraneous matter
- Can be used to remove fecal matter or ingesta < 1 cm^2
- Reduces general microbial load as well as *E. coli* O157:H7

Steam Vacuum

	Mean log reductions
E. coli O157:H7	
Steam Vacuum	3.11
Coliforms	
Steam Vacuum	2.70
SV + Hot Water	5.10

Nutsch et al., 1998 and Castillo et al. 1998

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Chemical Rinses

- Chlorine, Organic acids most commonly used
  - Organic acids – lactic, acetic, citric
- Improves microbiological quality of carcasses
- Other chemicals include Per-oxy acetic acid, Acidified sodium chlorite, CPC

Antimicrobial Agents: Classification

- Direct Food Additives
  - Sod. or Pot. Lactates, Buffered sodium citrate, sod. Diacetate and Lactoferrin, Irradiation
  - Considered ingredients, need to be labeled as such
- Secondary Direct Food Additives
  - Peroxy acids, ASC, Ozone
  - No labeling requirement

Organic Acid Use

- Organic acids, GRAS approved
  - Lactic, acetic, citric, ascorbic, etc.
  - Hot Carcasses – Processing aid
  - Chilled carcasses & Trim for Ground beef: Direct food additive
- How to use organic acids as processing aid?
  - Provide supporting data

Organic Acid Use

- How to use organic acids as processing aid?
  - Supporting data needed:
    - Fresh color of meat is not preserved
    - No extension in shelf life, should exhibit normal spoilage indicators (discoloration)
    - Nutrient composition not affected (protein not denatured; vitamins not enhanced)
    - Sensory characteristics not affected (color & odor)
    - No detectable residues of organic acid in meat

Chemical Rinses: CPC

	Days, Vacuum Packaged & Stored at 4°C		
	0	2	7
E. coli O157:H7			
Untreated	6.4	5.1	5.0
Water wash	3.9	3.2	2.8
1% CPC	ND	ND	ND
Total Counts			
Untreated	6.4	5.9	6.1
Water wash	4.1	4.0	4.1
1% CPC	0.6	0.3	0.6

No antimicrobial effect in ground beef

Cutter et al., 2000

Chemical Rinses: ASC

Carcasses*	WW	pASC	cASC
I. Round	1.8	3.0	3.1
Brisket	2.9	4.1	4.8
Flank	2.0	3.4	5.1

*Log CFU/g Reductions

Castillo et al., 1999

Chemical Rinses: Chl. dioxide and Ozone

Beef Trim	C#	CLO@	O-15@
E. coli	6.51	0.71	0.14
Coliforms	5.89	0.57	0.44
Salmonella	5.70	0.61	0.78

Initial Populations
@ Log CFU/g Reductions

Stivarius et al., 2002

Chemical Rinses: Acetic, Gluconic acids & Trisodium Citrate

Beef Trim	C#	A@	G@	TSC@
E. coli	6.51	0.9	0.29	0.14
Coliforms	5.89	1.25	0.19	0.05
Salmonella	5.70	1.47	0.10	0.18

Initial Populations
@ Log CFU/g Reductions

Stivarius et al., 2002

Chemical Rinses: Multiple Hurdles

Beef Trim	C#	AC@	CC@	CT@
Salmonella	5.81	1.98	1.38	1.17

Initial Populations
@ Log CFU/g Reductions

Pohlman et al., 2002

Irradiation

- Approved at 4.5 kGy for refrigerated meat products
- Approved at 7.0 kGy for frozen meat products
  - Organic acids – lactic, acetic, citric
- D_{10} Values:
  - *E. coli* O157:H7 : 0.27 (vac, 0°C), 0.31 (air, -16°C)
  - *Salmonella*: 0.62 (air, 4°C), 0.76 (air, -16°C)

Inactivation of Low Inoculum Levels of Pathogens

Dose (kGy)	*L.monocytogenes*	*Salmonella* Typhimurium	*E. coli* O157:H7
0	20 -1,600	30 – 380	30 - 45,000
1.1	<10	<10	<10 - 50
2.2	<10	<10	<10
3.3	<10	<10	<10
4.4	<10	<10	<10

ABC Research, NCBA

Summary of Pathogen Inactivation Rates

	D_{10}-Values (kGy) in Raw Red Meats	
	NCBA Gr. Beef Study	Literature
L. monocytogenes	0.72 - 1.25	0.45 - 1.21
Salmonella spp.	0.69 - 1.18	0.55 - 1.28
E. coli O157:H7	0.38 - 0.60	0.24 - 0.88

ABC Research, NCBA

Risk Mitigation Strategies: *E. coli* O157:H7 and STECs

- Approaches to food safety
- Sources of contamination
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  - Hide interventions
  - Carcass interventions
  - Post chill intervention
- Ranking of risk mitigation strategies
- Conclusions

Antimicrobial Interventions - Post Chill

Evaluation of peroxyacetic acid as a post-chilling intervention for control of *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on beef carcass surfaces

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Received 4 May 2004; received in revised form 24 August 2004; accepted 24 August 2004

Meat Science 69 (2005) 401–407

Post-Chill Interventions - PAA

	Fecal material, without added pathogens, applied to carcass surfaces		Fecal material, with rifampicin-resistant pathogens, applied to carcass surfaces	
	E. coli Type I	Coliforms	*E. coli* O157:H7	*S.* Typhimurium
Inside inoculated area[a]				
After water wash[b]	2.7b	2.9b	2.9	2.8a
After chilling[c]	3.8a	3.9a	2.7	1.6b
After peroxyacetic acid[d]	3.9a	4.1a	3.1	1.9b
SEM	0.2	0.2	0.4	0.2
Outside inoculated area[e]				
After water wash	1.3	1.5b	1.3	1.2a
After chilling	1.7	2.1a	1.1	0.4b
After peroxyacetic acid	1.8	1.9ab	1.0	0.4b
SEM	0.2	0.2	0.2	0.1

Least-squares means within a column and lacking common letters (a–c) differ ($P < 0.05$).
[a] Sample taken from 400 cm^2 to which fecal material was applied.
[b] Sample taken from hot carcass surfaces after gross fecal removal with manual and automated carcass wash.
[c] Sample taken from carcass surfaces following chilling at 4 °C for 48 h.
[d] Sample taken from chilled carcass surfaces after application of 200 ppm peroxyacetic acid and 10 min dwell type.
[e] Sample taken from outside the 400 cm^2 area to which fecal material was applied.

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A review of quantitative microbial risk assessment in the management of *Escherichia coli* O157:H7 on beef

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Received 15 March 2006; received in revised form 24 April 2006; accepted 24 April 2006

Meat Science 74 (2006) 76–88

Prevalence on beef

Prevalence and numbers of *E. coli* O157:H7 at various sample points along the beef chain in Ireland

Sample type	Sample numbers	Number positive (%)	Numbers present (Log_{10} CFU)	Reference
Bovine hide	1500	109 (7.3)	0.13–4.24/100 cm^2	O'Brien et al. (2005)
Beef carcasses	132	4 (3.0)	0.70–1.41/g	Carney et al. (2006)
Head meat	100	3 (3.0)	0.70–1.00/g	O'Brien et al. (2005)
Beef trimmings	1351	32 (2.4)	0.70–1.61/g	O'Brien et al. (2005)
Retail minced beef/burgers	1533	43 (2.8)	0.52–4.03/g	Cagney et al., 2004

Effectiveness of Risk Mitigation Strategies (Hypothetical)

Effect of different hypothetical risk mitigation strategies on reducing the probability of illness

Intervention	Model	Predicted reduction in illness (%)
Lowering average retail storage temperature to 8 °C from 10 °C with worst abuse case of 13 °C	Cassin et al. (1998) Lammerding et al. (1999)	80 80
Pre-slaughter treatment/screening of cattle to reduce the concentration of pathogen shed in faeces such that all contamination levels above 4 log CFU/g were eliminated	Cassin et al. (1998) Lammerding et al. (1999)	46 25
Information campaign targeting consumers to cook burgers resulting in a shift from 18.6% consuming rare or medium rare ground beef to 12% of such consumers	Cassin et al. (1998) Lammerding et al. (1999)	16 16
Use of hot water decontamination giving expected 1–4 Log_{10} reduction in STEC numbers on carcasses	Lammerding et al. (1999)	99.7
Irradiation of de-boned and frozen trimmings with 1 kGy giving an expected reduction of STEC numbers of 1.3–1.8 Log_{10}	Lammerding et al. (1999)	97
Eliminating or implementing stricter temperature controls for over-weekend chilling such that the maximum proliferation limited to the same as overnight chilling	Lammerding et al. (1999)	20

Impact of Parameters on Probability of Illness

Impact of various parameters along the beef chain on the probability of illness in consumed ground beef servings as determined by different risk assessment models

	Cassin et al. (1998)	Lammerding et al. (1999)	USDA-FSIS (2001) Ebel et al. (2004)	Duffy et al. (2006)
Sensitivity analysis of impact of factors on probability of illness in ascending order of importance	Concentration of pathogen in faeces	Concentration of pathogen in faeces	Surface area of carcass contaminated	Initial count on bovine hide
	Host susceptibility	Host susceptibility	Effectiveness of carcass chilling	Cooking temperature
	Carcass contamination factor	Dilution factor	Max. population of *E. coli* O157 in ground beef serving	Temperature abuse during transport and storage
	Cooking preference	Temperature of cooking	Home storage temperature	Hide to carcass contamination factor
	Retail storage temperature	Temperature of retail display		Hide Prevalence
	Decontamination during primary processing	Mass consumed		Change in numbers at carcass chilling
	Growth during processing	Washing		
	Retail storage time	Prevalence in faeces		
	Prevalence in faeces	Trimming		
	Mass ingested	Weekend chilling		

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Conclusions:

- Prevalence and load of *E. coli* O157:H7 and STECs in the cattle feces and hides can vary significantly
  - Day to day and
  - Season to season
- Significant differences within slaughter operations indicate practices can play a major role on prevalence of *E. coli* O157:H7
- Interventions need to be applied at various stages of beef slaughter and fabrication to mitigate the risk of *E. coli* O157:H7