Food Safety in Red Meats

Current Situation and Areas for Improvements

Farms, Processing Plants & Commerce

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Research Microbiologist
USDA-Agricultural Research Service
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Meat Safety and Quality Research Unit
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del CAMPO al PLATO

United State Department of Agriculture (USDA)

↓

Agricultural Research Service (ARS)

(one of the 29 Agencies)

↓

U.S. Meat Animal Research Center (USMARC)

(one of the 100 laboratories)

↓

Meat Safety and Quality Research Unit (MSQRU)

(one of the 6 RU)

The Roman L. Hruska U.S. Meat Animal Research Center

Mission is to Conduct research to solve problems related to beef cattle, sheep, and swine through multidisciplinary, integrated research approaches.

The Roman L. Hruska U.S. Meat Animal Research Center

- **35,000 acres (14,000 hectare)**
- **70 scientists**
- **200 support personnel**
- **50% of research is devoted to cattle, 30% to swine, and 20% to sheep**
- **Current population of:**
  - **5500 cattle**
  - **4000 sheep**
  - **600 litters of pigs**

USMARC Research Units

- Animal Health
- Nutrition
- Reproduction
- Genetics and Breeding
- Environmental Management
- Meat Safety and Quality

Meat Safety and Quality Research Unit

Meat Safety	Meat Quality
9 Scientists	3 Scientists
1 Post doc	1 Post doc
9 Technicians	5 Technicians

Meat Safety and Quality Research Unit

Focus on control, prevention and detection of foodborne pathogens entering the meat chain

In Animals

During Processing

In Finished Products





and at points before, between, and after

Meat Safety and Quality Research Unit

Focus on control, prevention and detection of foodborne pathogens entering the meat chain

In pigs and sheep


Processing of pork and lamb



Meat Safety and Quality Research Unit

Focus on control, prevention and detection of foodborne pathogens entering the meat chain

Shiga Toxin Producing *Escherichia coli*
(O157:H7 and non-O157)

Salmonella **(multi-drug resistant - MDR *Salmonella*)**

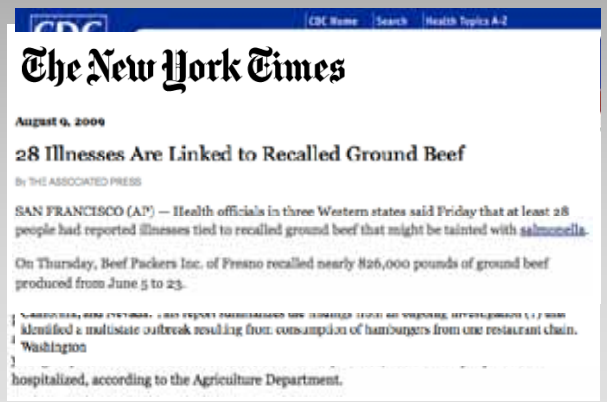
Campylobacter **(*C. coli* and *C. jejuni*)**

Listeria **(*L. monocytogenes*)**

Shiga Toxin Producing *Escherichia coli* (O157:H7 and non-O157)

- Shiga toxin producing *E. coli* live in the intestines of ruminant animals such as cattle, goats, and sheep.
- These *E. coli* generally do not make the animals sick, and other kinds of animals, like birds and wild pigs can even spread the *E. coli* through the environment to things such as produce items.
- The major source for human illnesses are attributed to cattle.
- An infected person may have severe stomach cramps, fever, vomiting, and bloody diarrhea. Most people get better within 5 to 7 days. However some infections can become severe and life-threatening.
- Very young children and the elderly are more likely to develop severe illness and hemolytic uremic syndrome (HUS) than others, but even healthy older children and young adults can become seriously ill.

Shiga Toxin Producing *Escherichia coli*
(O157:H7 and non-O157)



CDC Home | Search | Health Topics A-Z

The New York Times

August 9, 2009

28 Illnesses Are Linked to Recalled Ground Beef

By THE ASSOCIATED PRESS

SAN FRANCISCO (AP) — Health officials in three Western states said Friday that at least 28 people had reported illnesses tied to recalled ground beef that might be tainted with salmonella.

On Thursday, Beef Packers Inc. of Fresno recalled nearly 826,000 pounds of ground beef produced from June 5 to 23.

identified a multistate outbreak resulting from consumption of hamburgers from one restaurant chain. Washington

hospitalized, according to the Agriculture Department.

Shiga Toxin Producing *Escherichia coli*
(O157:H7 and non-O157)

Economic Loss to Foodborne Pathogens

- Five leading food-borne pathogens, *Campylobacter*, *Salmonella*, *E. coli* O157:H7, non-O157:H7 Shiga-toxin producing *E. coli* and *Listeria monocytogenes* account for nearly $7 billion of economic losses annually. (ERS/USDA 2001)

- As of 2003, nearly $2.7 billion in economic losses have been incurred by the U.S. beef industry because of *E. coli* O157:H7 alone. (Kay 2003, Meat & Poultry)

Shiga Toxin Producing *Escherichia coli*
(O157:H7 and non-O157)

The New York Times

OCTOBER 5, 2007, 2:35 PM

In a Beef Packager's Demise, a Whiff of Vichyssoise

By PATRICK J. LYONS

They won't be shipping beef patties from the Topps Meat Company plant in Elizabeth, N.J. much longer. (Mike Derer/Associated Press)

Facing the crushing cost of recalling more than 21.7 million pounds of ground beef that may have been tainted with e.coli bacteria, not to mention the near impossibility of rebuilding consumer trust in its products any time soon, the Topps Meat Company of Elizabeth, N.J. said today that it is going out of business, effective immediately.

Topps Meat

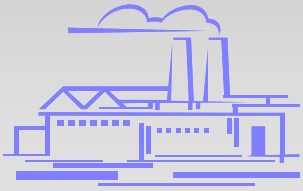
E. coli O157:H7 is Present Throughout the Beef Chain

Pasture cows and calves - Beef and Dairy herds

Feed lot pens - steers and heifers

Transport to slaughter plant

Through the stages of slaughter plant



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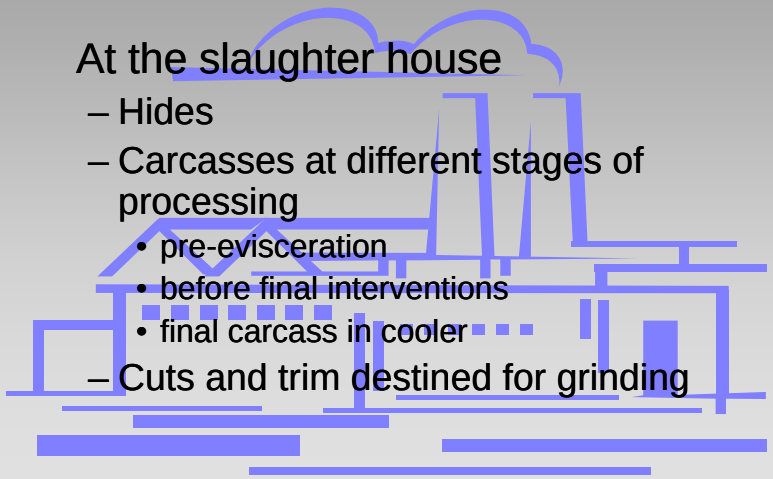


At the slaughter house

- Hides
- Carcasses at different stages of processing
  - pre-evisceration
  - before final interventions
  - final carcass in cooler
- Cuts and trim destined for grinding

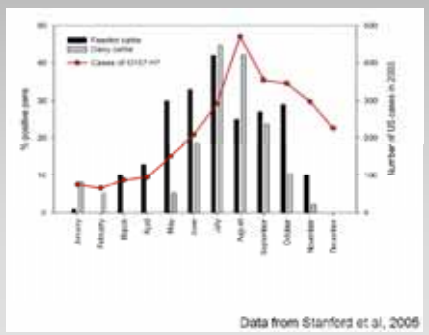
What Affects the Prevalence of *E. coli* O157:H7 in Live Animals

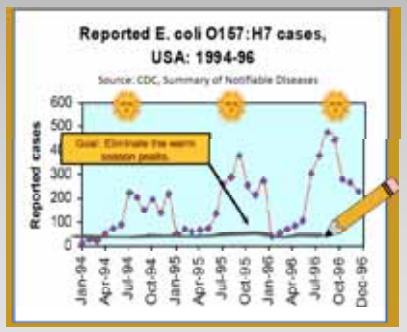
- Season (time of the year)
- Production system
  - Pasture or Feedlot
    - Calves on Pasture
    - Cattle in Feedlot
  - Diet
    - forage, hay, grain
    - distillers by products

E. coli O157:H7 is Seasonal

Summer months see the greatest prevalence in cattle, and increased human infections.

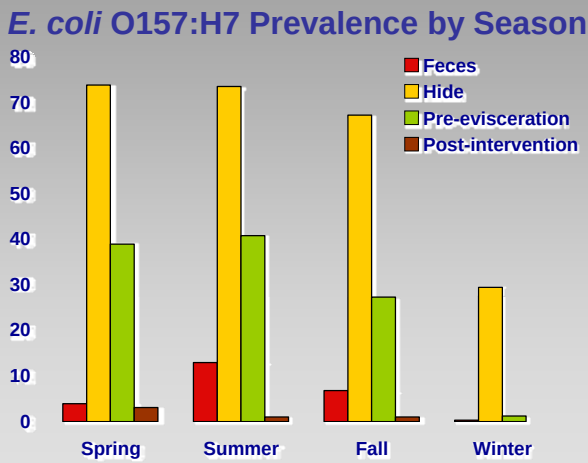
Winter months (January - March) show the fewest reported cases and lowest prevalence in cattle and slaughter houses.





Courtesy of Tom Besser, from Beef Industry Food Safety Consortium (BIFSCo) Meeting Oct. 13, 2010

E. coli O157:H7 is Seasonal



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Calves Coming off Pasture at Weaning

Fecal prevalence: 5.0%

Hide prevalence: 53.9%

Fecal prevalence for *E. coli* O157:H7

	Pen	1	2	3	4	5	6	7	8	9	10	Total
	Number of Cattle	35	36	30	32	30	31	29	32	32	32	319
Monthly	September	6	6	7	3	7	3	3	6	6	3	5
Monthly	October											
Monthly	November											
Monthly	December											
Monthly	January											
Monthly	February											
Bi-weekly	March											
Bi-weekly	April 04											
Bi-weekly	April 18											
Bi-weekly	May 02											

Values represent percent [%] of cattle with feces Positive for E. coli O157:H7

Fecal prevalence for *E. coli* O157:H7

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Monthly	September	6	6	7	3	7	3	3	6	6	3	5
Monthly	October	43	67	60	19	83	36	10	47	22	16	40
Monthly	November	34	61	67	38	67	39	10	72	63	38	49
Monthly	December	26	42	83	31	43	26	7	38	34	6	34
Monthly	January	3	8	10	6	23	3	3	19	3	3	8
Monthly	February	0	0	7	0	17	3	0	6	0	0	3
Bi-weekly	March	0	0	0	0	10	3	3	6	13	0	3
Bi-weekly	April 04	0	0	3	0	3	0	0	3	0	13	2
Bi-weekly	April 18	3	0	0	0	0	0	0	0	9	94	11
Bi-weekly	May 02	0	0	0	0	0	3	3	0	19	88	11

Values represent percent [%] of cattle with feces Positive for E. coli O157:H7

E. coli O157:H7 in feces correlates to *E. coli* O157:H7 on hides.

Especially in the feedlot

Hide samples are taken by scrubbing the cattle with a sponge at the shoulder

E. coli O157:H7 feces prevalence	Pen	1	2	3	4	5	6	7	8	9	10	Total
	Number of Cattle	35	36	30	32	30	31	29	32	32	32	319
	Sept 13	6	6	7	3	7	3	3	6	6	3	5
	Oct 18	43	67	60	19	83	36	10	47	22	16	40
	Nov 15	34	61	67	38	67	39	10	72	63	38	49
	Dec 13	26	42	83	31	43	26	7	38	34	6	34
	Jan 10	3	8	10	6	23	3	3	19	3	3	8
	Feb 7	0	0	7	0	17	3	0	6	0	0	3
	Mar 7	0	0	0	0	10	3	3	6	13	0	3
	Apr 4	0	0	3	0	3	0	0	3	0	13	2
	Apr 18	3	0	0	0	0	0	0	0	9	94	11
	May 2	0	0	0	0	0	3	3	0	19	88	11

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Jan 10	3	8	10	6	23	3	3	19	3	3	8
Feb 7	0	0	7	0	17	3	0	6	0	0	3
Mar 7	0	0	0	0	10	3	3	6	13	0	3
Apr 4	0	0	3	0	3	0	0	3	0	13	2
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E. coli O157:H7 feces prevalence

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Jan 10	3	8	10	6	23	3	3	19	3	3	8
Feb 7	0	0	7	0	17	3	0	6	0	0	3
Mar 7	0	0	0	0	10	3	3	6	13	0	3
Apr 4	0	0	3	0	3	0	0	3	0	13	2
Apr 18	3	0	0	0	0	0	0	0	9	94	11
May 2	0	0	0	0	0	3	3	0	19	88	11

E. coli O157:H7 hide prevalence

Sept 13	37	42	60	66	73	71	79	47	41	28	54
Oct 18	89	100	100	94	100	100	100	100	100	100	98
Nov 15	91	100	100	100	97	100	97	97	100	100	98
Dec 13	49	97	100	100	100	100	86	88	38	84	84
Jan 10	3	92	67	16	100	87	52	100	78	47	64
Feb 7	3	11	13	9	97	16	3	84	9	3	24
Mar 7	0	0	0	0	60	13	3	31	0	0	10
Apr 4	0	0	0	0	7	19	14	3	3	97	14
Apr 18	*66*	*44*	*63*	*56*	*27*	*84*	*59*	*38*	94	100	63
May 2	*3*	*17*	0	*6*	*3*	0	0	*6*	44	91	17

What Affects the Prevalence of *E. coli* O157:H7 in Live Animals

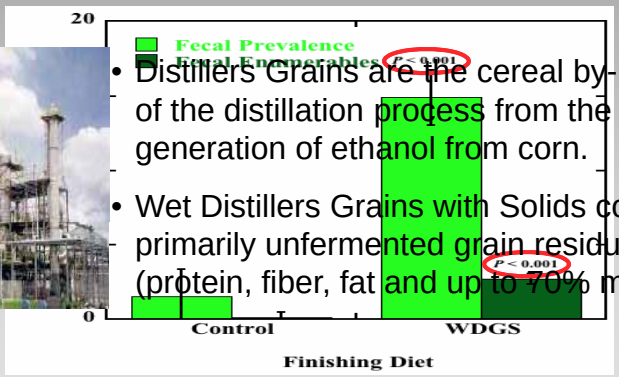
- Season (time of the year)
- Production system
  - Pasture or Feedlot
    - Calves on Pasture
    - Cattle in Feedlot
  - Diet
    - forage, hay, grain
    - distillers by products

Effects of Diet on Prevalence of *E. coli* O157:H7

- In general, research supports that cattle on grain-based diets shed higher levels of generic *E. coli* in their feces than cattle on high forage diets.
  - varying the forage-to-grain ratio in cattle rations can have an effect on *E. coli* population in cattle feces.
- A 2000 study showed that when cattle were switched to a hay diet, they had lower generic *E. coli* counts than cattle fed a corn diet prior to slaughter.
- Other studies have shown little to no reduction in fecal shedding of *E. coli* O157:H7 when cattle were switched to diets of hay.
- **Changes in diet can alter the *E. coli* O157:H7 shedding in cattle, but the observed change is inconsistent.**
- **One consistent contributor to increased *E. coli* O157:H7 is the feeding of distillers grains.**

Effects of Diet on Prevalence of *E. coli* O157:H7

The effect of finishing diets containing Wet Distillers Grains with Solids (WDGS)



- Distillers Grains are the cereal by-product of the distillation process from the generation of ethanol from corn.
- Wet Distillers Grains with Solids contain primarily unfermented grain residues (protein, fiber, fat and up to 70% moisture).

Fecal prevalence and percent of fecal samples with enumerable *E. coli* O157:H7 were significantly different for the pens.

What Affects the Prevalence of *E. coli* O157:H7 in Live Animals

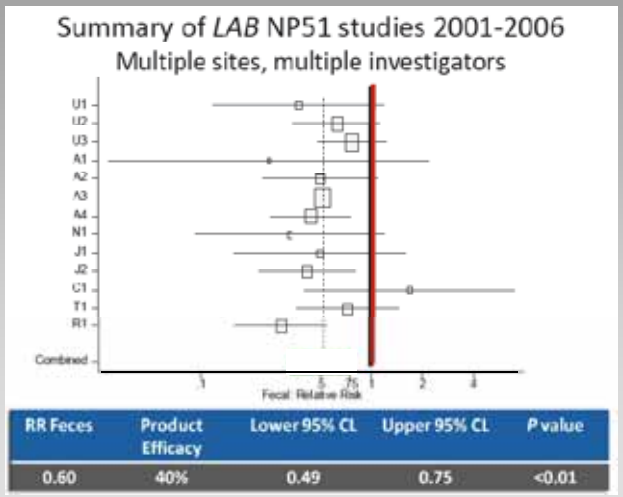
- Seasons
  - Diet (time of the year)
- Production system
  - Vaccines
  - Pasture or Feedlot
    - Calves on Pasture
    - Cattle in Feedlot
  - Diet
    - forage, hay, grain
    - distillers by products

Effect of a Probiotic (DFM) on the Prevalence and Load of *E. coli* O157:H7 in Feedlot Cattle

	Feces % Prevalence		Fecec % high shedders	
Day	CONTROL	DFM	CONTROL	DFM
-7	24.6	23.9	4.7	4.3
0	16.8	10.2	4.3	2
28	12.1	12.1	3.9	0.8
63	14.5	12.9	5.1	5.5
84	28.9	22.7	13.7	10.6

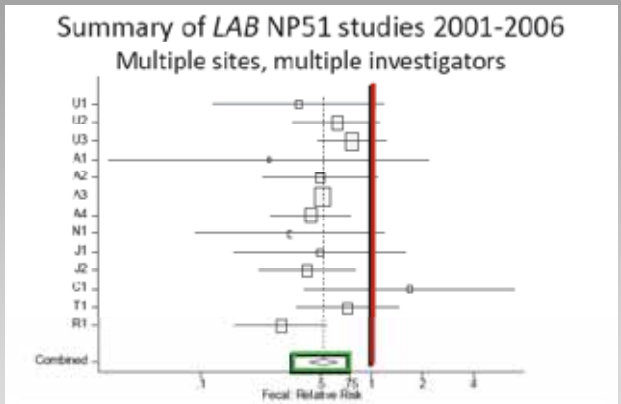
Cattle (n ~ 526) were divided among 16 feedlot pens. Half of the pens received the DFM, and the other half did not. Hide and fecal samples were collected from each animal on days 28, 63, and 84 of the feeding trial. Over the course of the 84-day feeding period, there were no significant differences observed between treatments for either hide or fecal prevalence of E. coli O157:H7, or for the percentage of animals that were shedding E. coli O157:H7 at high levels.
Arthur *et al.* 2010. *J Food Prot* 73:366.

Meta-Analysis of Multiple Studies of Another DFM, *LAB NP51*,



Loneragan 2010.

Meta-Analysis of Multiple Studies of Another DFM, *LAB NP51*, Does Show an Effect



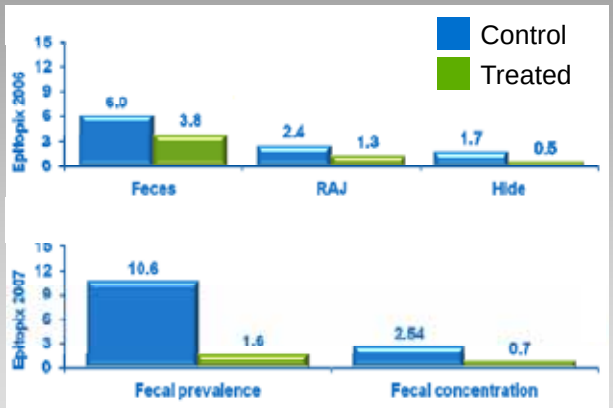
RR Feces	Product Efficacy	Lower 95% CL	Upper 95% CL	*P* value
0.60	40%	0.49	0.75	<0.01

Loneragan 2010.

What Affects the Prevalence of *E. coli* O157:H7 in Live Animals

- Interventions
  - – Probiotics
  - – Vaccines

Summary of *E. coli* O157:H7 Vaccine Studies (2006 & 2007)



Epitopix vaccine, source of data D. Thomson, Kansas St. Univ. - **Loneragan 2010**

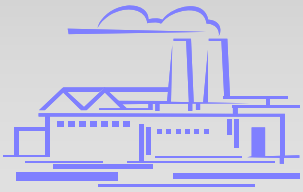
E. coli O157:H7 is Present Throughout the Beef Chain

Pasture cows and calves - Beef and Dairy herds

Feed lot pens - steers and heifers

Transport to slaughter plant

Through the stages of slaughter plant



What Affects the Prevalence of *E. coli* O157:H7 on Animals Between Feedlot and Slaughter House

Trucks

Holding Pens

Ally ways

E. coli O157:H7 Hide Prevalence Before and After Transport

Trial #	Feedlot	Plant
1	28%	89%
2	74%	96%
3	21%	100%

Hides sampled when leaving feedlot

Hides sampled after stunning

What are the sources?
- Animals - advantages of [illegible] ed [illegible] post contamination?
- Trucks - how clean were th [illegible] s b [illegible] contamination?
- Lairage (pens & ally-ways) - assumed to be conta [illegible] ut what is impact?

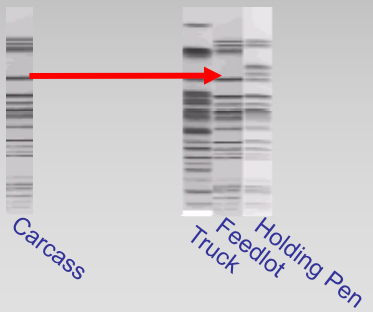
Transport and Lairage Study

- Cattle hide & feces sampled at the feedlot
- Trucks sampled prior to loading cattle
- Lairage environment at slaughter house sampled
- Hides and carcasses sampled at slaughter house
- All *E. coli* O157:H7 was “finger printed” for source tracking

Transport and Lairage Study

Tracking *E. coli* O157:H7 using genomic fingerprints

- Fingerprint tracking can be used to determine sources of bacterial contamination
- Unrelated strains have unique fingerprints



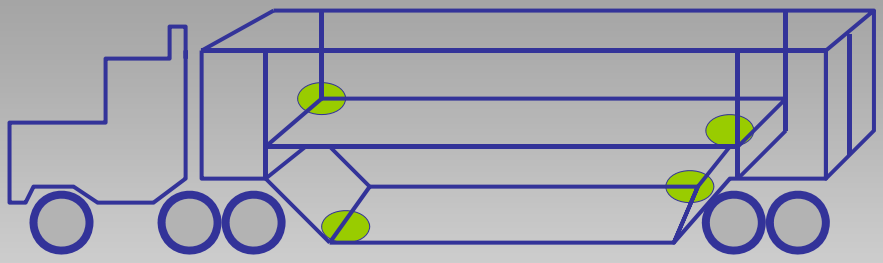
Transport and Lairage Study

Cattle hides & feces sampled at the feedlot

All *E. coli* O157:H7 fingerprints from the Feedlot will be red

Transport and Lairage Study

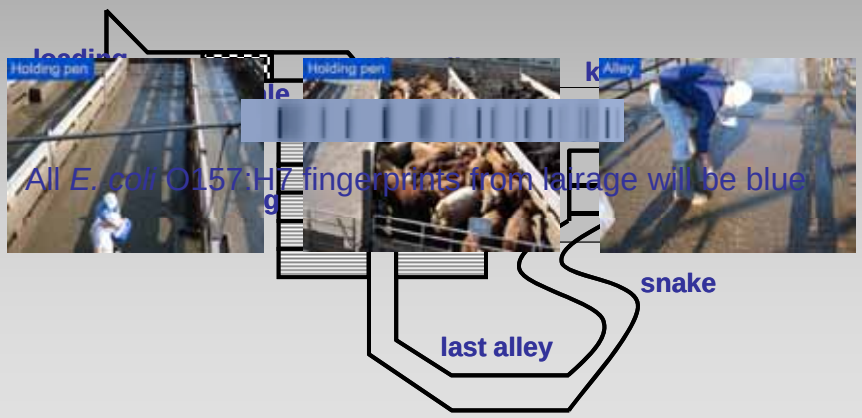
Trucks Sampled Prior to Loading Cattle



E. coli O157:H7 was found in all trucks, clean and dirty.
All *E. coli* O157:H7 fingerprints from trucks will be green

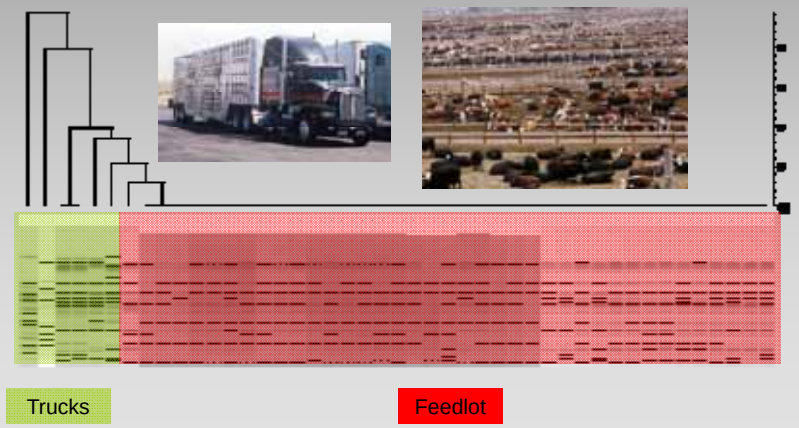
Transport and Lairage Study

Lairage Environment at Slaughter House Sampled



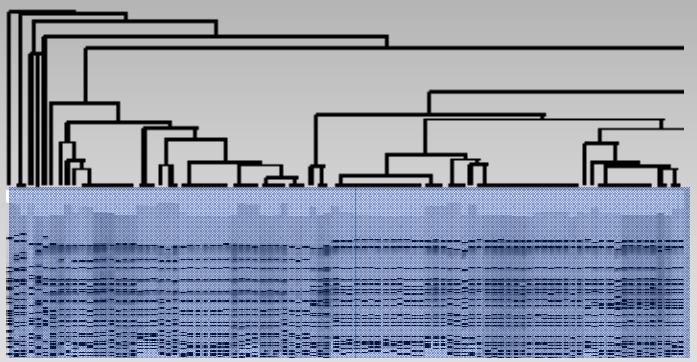
Transport and Lairage Study

***E. coli* O157:H7 Fingerprints from Feedlot and Trucks Collected When Cattle were Loaded for Transport**



Transport and Lairage Study

E. coli O157:H7 Fingerprints from Lairage Pens and Ally-ways at Slaughter House



Lairage Types

Transport and Lairage Study

E. coli O157:H7 Fingerprints from Hides and Carcasses Collected at Processing Plant

Lairage Types | Trucks | Feedlot Types

* = pre-evisceration carcass isolate

E. coli O157:H7 Fingerprints Show Sources of Carcass Contamination on Hides and Carcasses at the Slaughter House

	# of isolates	Feedlot types	Truck types	Lairage types
Total	764	39%	2%	59%
Total	80	16%	1%	83%

Transport and Lairage Study

- Conclusions
  - Cattle can be contaminated by trucks
  - Cattle can be contaminated in pens and ally-ways
  - A significant portion of carcass contamination is not associated with the feed lot
- Options and treatments that reduce this contamination need to be identified
  - Live animal wash in lairage
  - Hide wash after stunning

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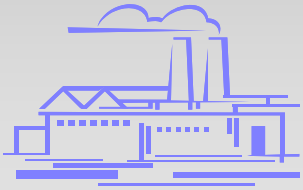
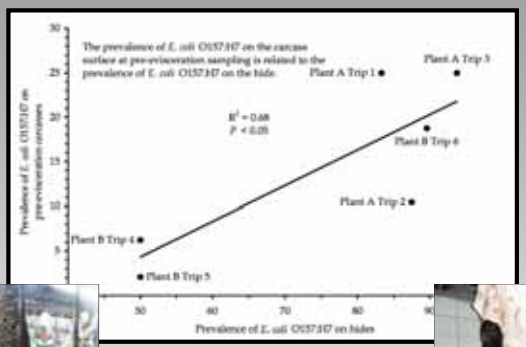


E. coli O157:H7 on Hides Correlates to *E. coli* O157:H7 on Pre-evisceration Carcasses



During the steps of hide removal *E. coli* O157:H7 can be transferred from the hide to the carcass.

Does the Size and Speed of a Processor Affect Transfer of Pathogen and Contamination of the Carcass?

Large

1000's of cattle per day

100's of employees

Fast chain speed (300/hr)

Ample resources, (capital and human) newer equipment, training and interventions

Medium/Smaller

100's of cattle per day

<250 employees

Slower chain speed (50-150/hr)

Usually have limited resources compared to large processors

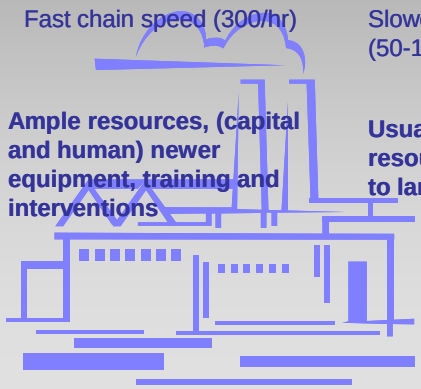
Very Small

<100 cattle per day

5-50 employees

5-20 head/hr

Very limited resources, just the required minimum



Comparison of *E. coli* O157:H7 Prevalence on Hides and Pre-evisceration Carcasses at Slaughter Houses of Different Sizes

***E. coli* O157:H7 Prevalence (%)**

Medium/Smaller Cull Cattle Plants (n=760/plant)

	A	B	C	D	Average
Hide	30	28	64	66	47
Carcass	12	7	7	42	17

Large Fed Beef Plants

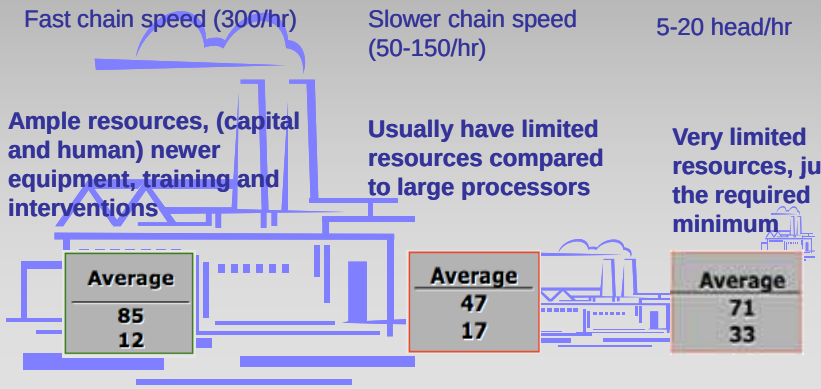
	1	2	3	A	B	C	Average
n=	81	149	56	222	174	185	
Hide	89	95	100	89	98	38	85
Carcass	2	13	11	38	2	6	12

Small/Very Small Processing Plants (n=285/plant)

	1	2	3	4	5	6	7	Average
Hide	94	83	56	86	80	34	64	71
Carcass	57	44	35	17	56	8	12	33

Does the Size and Speed of a Processor Affect Transfer of Pathogen and Contamination of the Carcass?

Large	Small	Very Small
1000's of cattle per day	100's of cattle per day	<100 cattle per day
100's of employees	<250 employees	5-50 employees
Fast chain speed (300/hr)	Slower chain speed (50-150/hr)	5-20 head/hr
Ample resources, (capital and human) newer equipment, training and interventions	**Usually have limited resources compared to large processors**	**Very limited resources, just the required minimum**



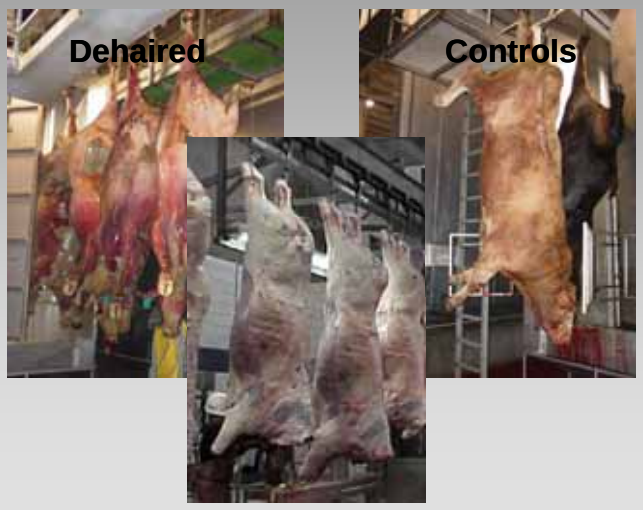
Areas to Improved Carcass Cleanliness in the Slaughter House

- Lower the amount of *E. coli* O157:H7 transferred to the carcass during hide removal.
  - Hide wash after stunning
  - Better training of employees
- Decontaminate the pre-evisceration carcass
  - Wash with hot water or acid
  - Use continuous knife trimming
  - Use steam vacuums
- Decontaminate the final carcass and de-boned meat cuts.

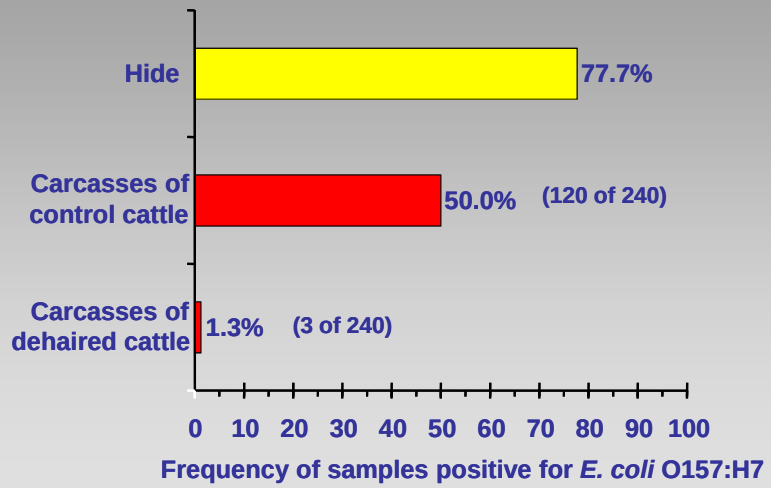
Hide Directed Intervention Reduces *E. coli* O157:H7 Carcass Contamination

- Eliminating or reducing *E. coli* O157:H7 on hides will prevent or reduce carcass contamination.
- Demonstrated using chemical dehairing

Compared the *E. coli* O157:H7 that was transferred from dehaired animals and controls to pre-evisceration carcasses



Dehairing of cattle before hide removal reduces the prevalence of *E. coli* O157:H7 on pre-evisceration carcasses



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Effects of Best Practices Training

Before	Hide Prevalence	Carcass Prevalence
1	84%	74%
2	100 %	69%
3	60 %	36%
4	100 %	58%
5	47 %	28%
6	36 %	31%
Mean	**71%**	**50%**

After	Hide Prevalence	Carcass Prevalence
1	72%	8%
2	67%	9%
3	84%	10%
Mean	**74%**	**9%**

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Pre-Evisceration Carcass Washing

Lactic Acid and Hot Water Wash Treatments of Pre-evisceration Carcasses Reduce the Prevalence of *E. coli* O157:H7

	Lactic Acid (n = 256)	Hot Water (n = 256)	Both (n = 256)
Before Treatment	31%	27%	19%
After Treatment	20%	5%	4%
Reduction	35%	81%	79%
P value	0.01	0.001	0.001

- Pre-evisceration wash is an effective processing aid used to reduce microbiological levels.
- Carcasses wash can be hot water, organic acid or other antimicrobial chemical.
- Large mass flow of wash ~350 L per carcass

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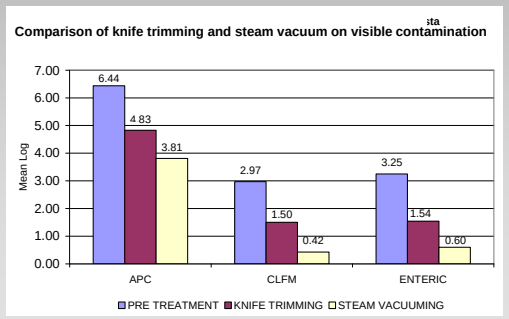
Steam Vacuum

- Early application of steam is critical, before bacterial attachment occurs.
- Only a “spot treatment” and not a whole carcass treatment.

Steam Vacuum

- Steam vacuums are used over hind hocks, and the hide opening patterns
- Steam is also used to blow off contaminants from the hock
- Continuous knife trimming of visible contamination



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Steam Pasteurization and Hot Water Treatment Improves Safety of Final Carcasses

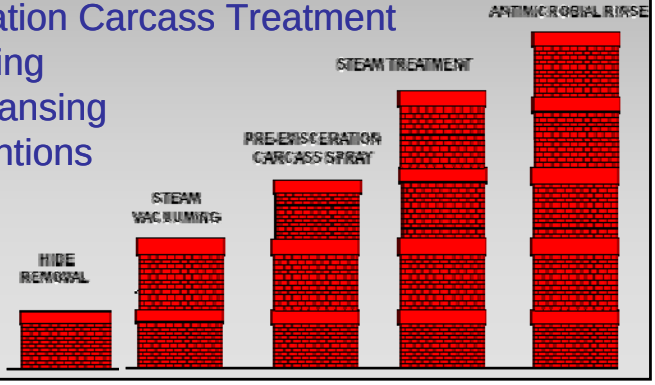
Treatments to Improve Safety of Subprimal Beef Cuts, De-boned Beef and Trim

- Prior to vacuum packaging, all primals and subprimals are treated with an antimicrobial spray as a final step.

- Prior to grinding, all trim is treated with an antimicrobial spray.

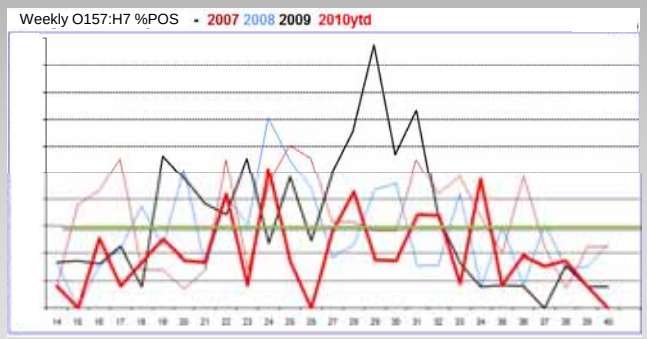
The Multiple Hurdle Approach of Beef Slaughter Systems Reduces Foodborne Pathogens at Each Step

- Hides removal
- Steam Vacuums to Treat Patter Marks
- Pre-Evisceration Carcass Treatment
- Knife Trimming
- Carcass Cleansing
- Trim Interventions



The Multiple Hurdle Approach of Beef Slaughter Systems Reduces Foodborne Pathogens at Each Step

The prevalence of weekly positive *E. coli* O157:H7 tests on boneless beef trim shows the effect of integrating new interventions and treatments.



New treatment began in 2010

Foodborne Pathogens are Present Throughout the Beef Chain

We must constantly examine processes and identify ways to improve them for food safety

The New York Times

November 3, 2009

E. Coli Kills 2 and Sickens Many; Focus Is on Beef

Two people, one from New Hampshire and another from upstate New York, have died after eating ground beef that may be responsible for an E. coli outbreak linked to illness in more than two dozen people.