Research Developments in Pathogen Reduction During Slaughter and Meat Processing

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Numbers of enteric pathogens on meat can be reduced by

Preventing contamination

and/or

Decontamination

Research on decontamination is predominant

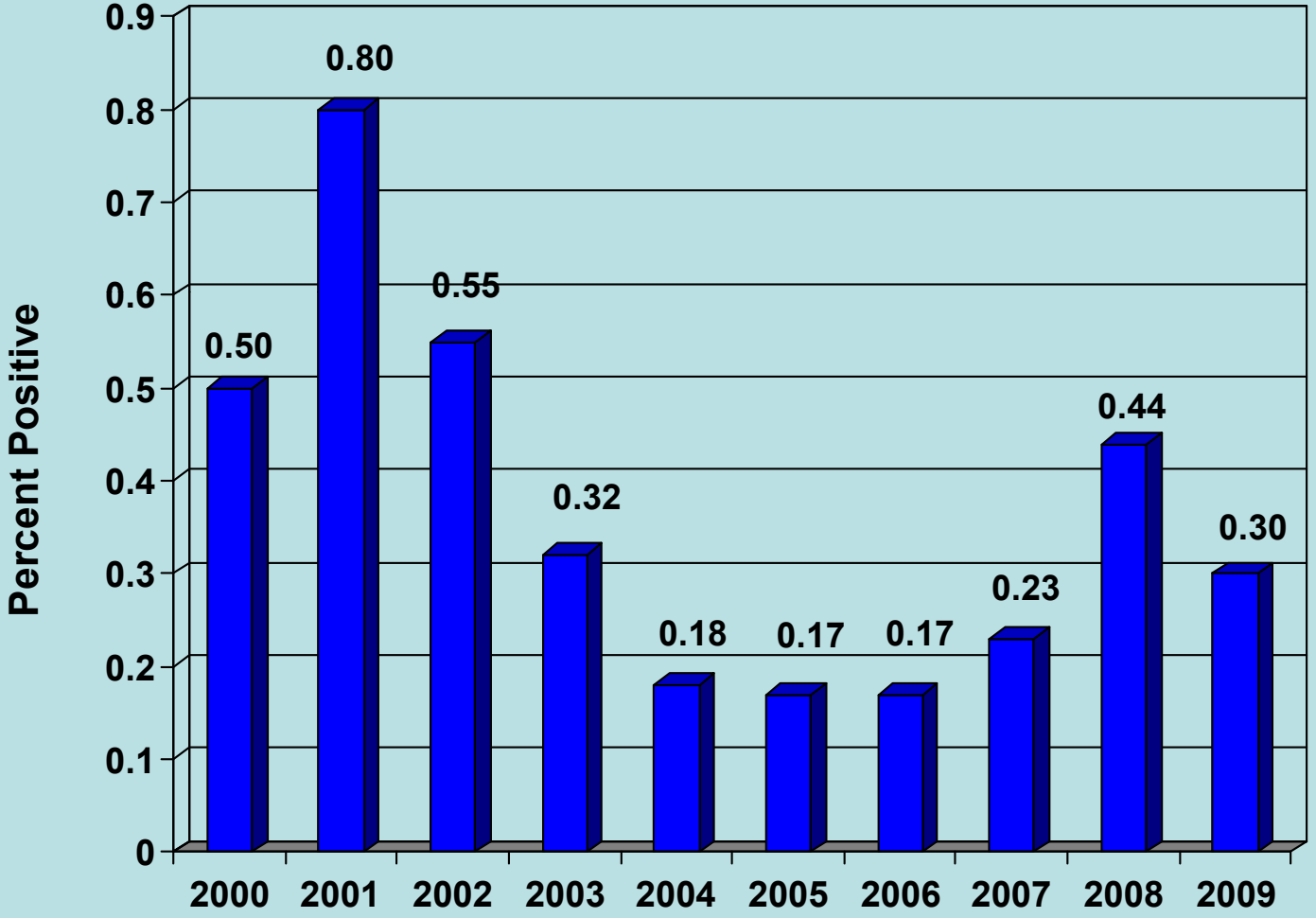
Matters to be Discussed

Studies reported during the past 5 years on

- **Control of *Escherichia coli* 0157:H7 on beef**
- **Control of *Listeria monocytogenes* on ready-to-eat meats**

FSIS Raw Ground Beef Testing

Percent Positive *Escherichia coli* 0157:H7
Initial Federal Verification Samples (Figure 1)



Improving Control over *E.coli* O157:H7 in Beef

Regulators' Response:

INCREASE TESTING

ENHANCE TEST SENSITIVITY

WHY ?

"Regulatory testing is not designed to directly ensure food safety."

"Rather, regulatory testing strategies stimulate implementation of effective interventions and prevention---"

"Regulation allocates, not assumes, responsibility."

Dodd, C. I., Powell, D., 2009. Foodborne Pathogens and Disease 6, 743-747.

HACCP System Validation

- **Necessary part of any HACCP System**

- **Validation is stipulated in USDA HACCP System Final Rule 1996 But no details provided**

- **USDA HACCP Systems Validation: Draft Guidance Document 19th March 2010**

Requirements for each HACCP system

1. Scientific support

2. In-plant validation

Enumeration of indicator organisms and testing for pathogens is suggested

Improving Control Over *E.coli* 0157:H7 in Beef

Where to Improve Control?

1. Carcass Dressing

"The function of preharvest intervention is to reduce the load of *E.coli* O157:H7 on the incoming cattle to bring the load in line with the capacity of the postharvest intervention used."

Arthur, A.T. et al., 2009. Appl. Environ. Microbiol. 75, 6515-6523.

Experimental Decontamination of Hides

Treatment	Reductions (log cfu)			
	Aerobes	Coliforms	*E.coli*	Ref.
Water	0.2	_	_	
Peroxyacetic acid	0.6	_	_	1
Quat sanitizer	1.8	_	_	
Clipping and singing	2.1	_	_	
Water	_	1.6 (3.6)[a]	_	2[b]
4% Chlorine release compound	_	3.9 (4.4)	_	
4% Phosphoric acid	_	4.1 (5.4)	_	
1.6% NaOH	_	3.7 (3.9)	_	
water	1.0	0.6	0.9	
10% Acetic Acid	2.5	2.6	2.6	3
10% Lactic acid	2.2	2.7	2.7	
3% NaOH	1.5	2.9	2.8	

[a]Reduction after vacuuming to remove water

[b]Treatment followed by rinse with water containing 500 ppm chlorine

1. Small et al., 2005 Meat Sc.i 69 (1), 263-268
2. Bosilevac et al. 2005. J. Food Prot. 68 (2) , 265-272
3. Carlson et al, 2008. J. Food Prot. 71(7), 1343-1348

Decontamination of Inoculated Hides

Treatment	Reduction (log cfu)	
	E.coli O157:H7	Salmonella
Water	2.3	1.7
10% Acetic acid	2.6	2.0
10% Lactic acid	3.4	2.8
3% NaOH	3.4	4.4
2.4% KOCN	5.1	0.7
6.2% NaS	4.8	4.2
10%NaOH +2000 ppm Cl	5.0	4.4

Carlson et al., 2008. J. Food Prot. 71 (11), 2223-2227

Decontaminating effects of a Commercial Hide Wash Cabinet

Manufacturer: CHAD

Treatment: 1.0-1.5 % NaOH at 65 °C, 700 psi, 1500 l/min, 10 s

	Reductions		
	Hides minus washed hides	Hides minus skinned carcasses,hide washed	Hides minus skinned carcasses, hide not washed
Aerobes	2.1	5.4	4.5
Enterobacteriaceae (log cfu)	2.4	5.4	4.7
E. Coli O157:H7 (%)	-28[a]	-42[a]	-71[b]

[a]Prevalence on hides, 44%
[b]Prevalence on hides, 88%

Bosilevac et al., 2005. J. Food Prot. 68 (2), 265-272.

Spraying Hides with Shellac

Treatment; spray with 23% shellac in ethanol at 20 ^{o}C

Count	Reduction (log cfu)
Aerobes	6.6
Enterobacteriaceae	4.8
E.coli	2.9

Antic et al., 2110. Meat Sci. 85 (1), 77-81

Decontamination of Skinned Carcasses in a Commercial Cabinet

Manufacturer: CHAD

Treatment : Wash with water at 74 °C, 700 psi for 5.5 s, then spray with 2 % lactic acid

	Reductions		
	Water only	Acid only	Water & Acid
Aerobes (log cfu)[a]	2.7	1.6	2.2
Enterobacteriaceae (log cfu)[b]	2.7	1.0	2.5
E. coli O157:H7 (%)	-5.5	-29	-39

[a]Numbers before treatment were > 4 log cfu/cm^2
[b]Numbers before treatment were >2 log cfu/cm^2
[c]Prevalences before treatment with water, acid and both were >9, 69 and 48%

Bosilevac et al., 2006. J. Food Prot. 679 (8) 1808-1813.

Commercial Decontamination of Skinned Carcasses

Effects on prevalence of *E.coli O157:H7*

Data from three plants, each of which "used a pre-evisceration carcass wash with organic acid".

	Before treatment	After treatment	Reduction
E. coli 0157:H7 Prevalence %	10.1	1.4	-8.7

Woerner et al., 2006. J. Food Prot. 69(12), 2824-2827

Commercial Decontamination of Skinned Carcasses

Previous Findings

Plant	Reductions (Log cfu)[a]			
	Aerobes	Ent.	Coliforms[b]	*E.coli* [b]
A	0.5	-	1.3	0
B	0.4	-	<0.1	0.1
C	0	-	1.2	1.2
D	0.1	0.3	-	-
E	+0.6	+0.4	-	-

[a]Plants A B &C, before and after treatment; plants D & E before treatment and after treatment and evisceration

[b]Reductions in log total numbers recovered from 2500 cm^2

Plants A, B &C; Gill & Landers 2003. Meat Sci 65 (3), 1005-1011.
Plants D & E; Arthur et al. 2004. J. Food Prot. 67 (4), 658-665.

Origin of *E.coli* in Ground Beef

Beef side surface area= 60 000 cm^2 (3x 2 m^2)

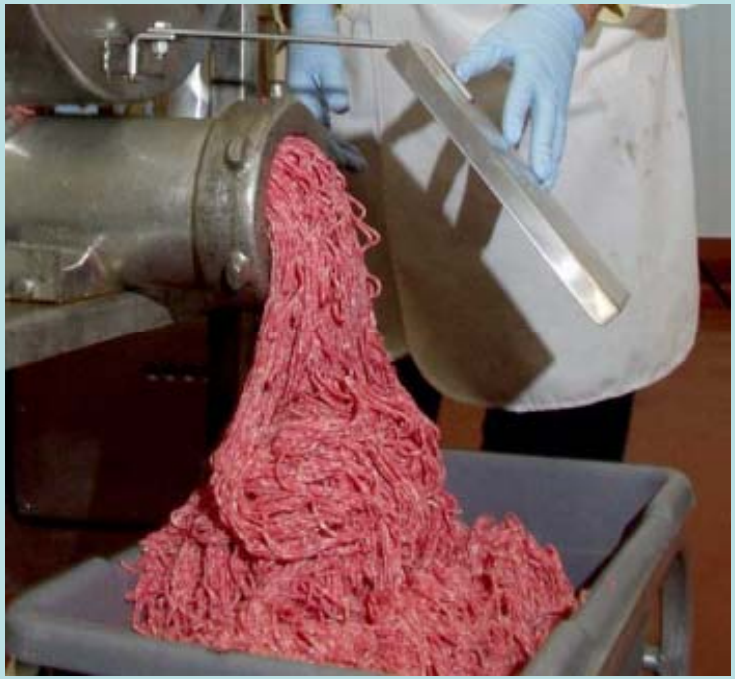
Beef side weight =150 000 g (150 kg)

Which gives 70 000--- 120 000 g of ground beef

Therefore, if all *E. coli* in ground beef are present on carcasses,

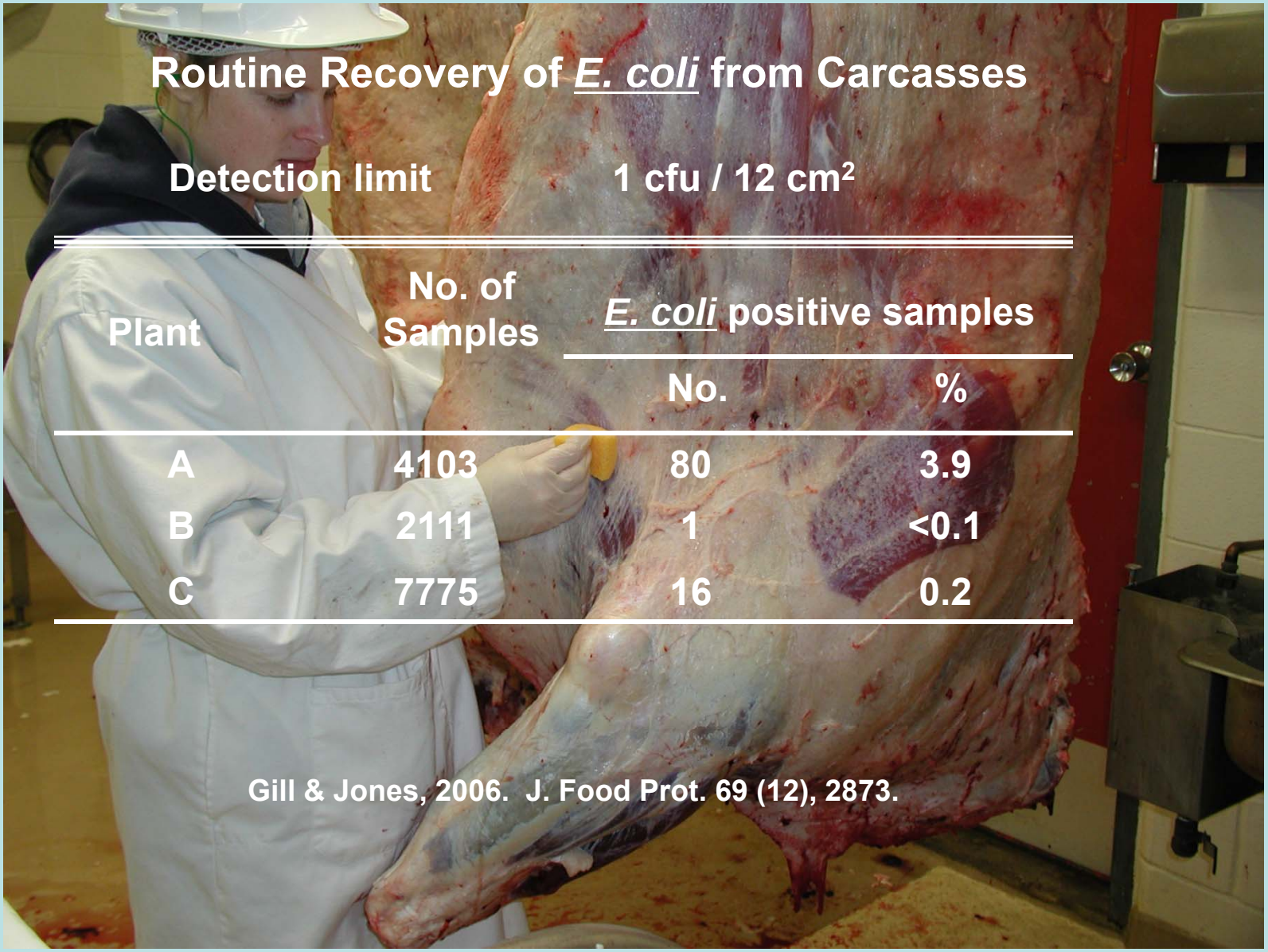
***E. coli* /g ground beef ≈ *E.coli* / cm^2 carcass surface**

Mean numbers of *E.coli* in ground beef at plants is 5/g



But, USDA criteria require that no more than 3 of 13 carcass samples have ≥ 5 E. coli /cm^2

Therefore, either most plants do not meet USDA criteria or beef is contaminated after carcass dressing



Routine Recovery of *E. coli* from Carcasses

Detection limit 1 cfu / 12 cm^2

Plant	No. of Samples	*E. coli* positive samples	
		No.	%
A	4103	80	3.9
B	2111	1	<0.1
C	7775	16	0.2

Gill & Jones, 2006. J. Food Prot. 69 (12), 2873.

Prevention of Product Recontamination

No reported work on prevention of recontamination

But

E.coli **O157:H7 attached to stainless steel have been shown to survive drying for 12 h**

Attachment Conditions		*E. coli* 0157:H7 (log cfu/cm^2)	
Temp ^{o}C	Time (h)	Before drying	After drying
35	7	2.3	<0.3
	24	4.5	2.5
15	24	2.0	0.5
	48	3.1	0.6

Skandamis et al., 2009. Food Microbiol. 26 (1), 112-119.

Decontamination of Beef by Heat

All reported work was done with inoculated product; products were variously trim, primals, heads and hearts

Treatment			Reduction (log cfu)		
Temp (°C)	Time (s)	Application	*E.coli* 0157:H7	*S.* Typhimurium	Ref.
82	15	Water, dipping	--	0.5	1
82	20	Water, spray	0.9	-	2
74	26	Water, spray	1.7	-	3
85	12	Water, spray	2.3	2.5	4
	28	Water, spray	2.4	2.8	
>80	60	Steam	2.5	3.7	5
90	60	Hot air	4.2	4.7	6
100	60	Hot air	3.9	6.0	

1. Özdemir et al. 2006. food control 17(2), 299-303.
2. Heller et al. 2007. J. Food Prot 70 (50, 1174-1180.
3. Halchayanand et al. 2008. J. food Prot. 71 (3), 621-624.
4. Halchayanand et al. 2009. J. food Prot. 72 (1), 151-156.
5. McCann et al., 2006. J. Food Engineer. 76 (1), 32-40.
6. McCann et al., 2006. J. Appl. Microbiol. 101 (5), 1177-1187

Decontamination of Beef with Antimicrobial Solutions

All reported work was done with inoculated products; products were variously trim, primals, heads and meats

Treatment	Reductions (log cfu)		
	E.coli 0157:H7	*S.* Typhimurium	Ref.
0.1% peroxyacetic acid, 2% lactic acid	0.7, 1.3	1.0, 2.1	1
2% lactic acid, 85 °C water+ 2% lactic acid	-	0.7, 1.2	2
5% lactic acid, 2% lactoferrin +5% lactic acid	1.1, 0.9	-	3
Fresh FX[a], Electrolysed water, Ozone	1.1, 0.3, 0.4	-	4
270 ppm bromine release agent [b]	2.1	-	5

[a] Mixture of Hydrochloric, phosphoric and citric acids
[b]Dibromo-dimethyl-hydantoin

1. Ellebracht et al., 2005. Meat Sci 70 (2), 197-203.
2. Ozdemir et al., 2006. Food Control 17- (2), 299-303.
3. Heller et al., 2007. J. Food Prot. 70 (5), 1174-1180.
4. Kalchayanand et al., 2008. J. Food Prot 71 (3), 621-624.
5. Kalchayanand et al., 2009. J. Food Prot. 72 (1), 151-156.

Sanitizers and *L. monocytogenes* Biofilms

1. Sanitizers based on peroxyacetic, acetic and/ or phosphoric acids, H_2O_2 , ethanol, isopropanol and/or quats are all effective at 5 ^oC.

2. A H_2O_2 / peroxyacetic acid sanitizer was more effective than chlorine or quat based sanitizers.

3. Lactic acid was more effective than NaOCl or quat based sanitizers.

4. Reuterin in combination with NaOCl, nisin or phosporic acid was effective as a sanitizer.

5. Sanitizers based on essential oils of lemongrass or citronella were effective.

1. Aarnisalo et al., 2007. LWT Food Sci. Technic..40 (6) 1041-1048.
2. Berrange et al. 2008. J. Food Prot. 71 91), 66-69.
3. Yang et al. 2009 J. Food Prot. 72 (5), 990-998.
4. El- Ziney & Jacobsen 2009. J. Food Agri. Environment. 7 (3-4), 145-149.
5. De Oliveira et al. 2010. Food Control 21 (4), 549-553.

Inactivation of *L. monocytogenes* in Brines

1. D-values for *L.monocytogenes* in 20% NaCl or 20% $CaCl_2$ were 12.3 and 0.5 days, respectively; with 3 ppm ClO_2, D-values were 24 and 22s;
   with ≥ 1% organic matter, ClO_2 had no effect.

2. UV light inactivated *L. monocytogenes* in fresh brines; but was ineffective against *L. monocytogenes* in brine containing 0.1% suspended solids.

3. Bacteria in turbid solutions may be inactivated by continuous or pulsed UV light if liquid flow is turbulent.

1. Valderram et al., 2009. J. Food Prot. 72 (11), 2272-2277.

2. Gailunas et al., 2008. J. Food Prot. 71(3), 629-633.
   McKinney et al., 2009. J. Food Prot 72 (8) 1634-1640.
   McKinney et al., 2009. J. Food Prot. 72 (10), 2144-2150.

3. Krisnamurithey et al., 2007. J. Food Sci. 72(7), M233-M239.
   Keyser et al., 2008. Innovat. Food Sci. Emerg. Technol. 9, 348-354.

Inactivation of *L.monocytogenes* on Packaged Products with Pulsed UV Light

1. **Packaging films do not affect inactivation by pulsed UV**

2. ***L. monocytogenes* on illuminated surfaces of packed frankfurters were reduced by 2 log units**

1. Fernandez et al., 2009. Foodborne Pathogens and Disease 6 (10), 1265-1263.
2. Keklik et al., 2009. J. Food Sci 74 (8), M431-M439.

Pasteurization of Frankfurters

1. Steam pasteurization (114 °C, 1.5 s) of franks in two layer packs reduced *L. monocytogenes* numbers by 3 log units. Reductions were greater (<1 log unit) if franks, were treated with liquid smoke or an organic acid solution before pasteurizing.

2. Steam pasteurizing (121 °C, 1.5s) of franks in single-layer packs reduced *L. innocua* numbers by 2 log units. No growth occurred during storage of pasteurized franks containing lactate and diacetate.

3. When single-layer vacuum packs of franks were pasteurized at 85 °C by microwave or hot water heating, rates of reduction of *L. monocytogenes* were 0.9 and 0.6 log cfu /min, respectively.

1. Murphy et al., 2005. J. Food Prot. 68 (3), 507-511.
   Murphy et al., 2005. J. Food Sci. 70 (2), M138-M110.
2. Murphy et al., 2008. J. Food Sci. 73 (2), M72-M74.
3. Huang & Sites, 2007. J. Food Engineer. 80 (2), 226-233.

High Pressure and Irradiation Treatments of Dry Cured Ham and Frankfurters

1. High Pressure Treatment of sliced dry cured ham (450 MPa, 10 min 12 ^{o}C) reduced *L. monocytogens* numbers by 1 log unit. Numbers fell by a further 1 to 2 log units during storage for 1 week.

2. Explosive high pressure treatment of vacuum packaged franks reduced *L. monocytogenes* numbers by 1 log units. Dipping in nisin solution before packaging and high pressure treatment reduced numbers by a further 0.5 log unit.

3. D-values for irradiation of *L. monocytogenes* and *L. innocua* on dry cured ham were 0.42 and 0.47 kGy, respectively.

1. Morales et al., 2006. J. Food Prot. 69 (10), 2539-2543.
2. Patel et al., 2007. J. Muscle Foods 18 (1), 1-18.
3. Hoz et al., 2008. J. Food Prot. 71 (10), 2001, 2006.

Spraying Processed Meats with Antimicrobial Solutions

1. **Acidic or basic electrolysed waters reduced *L. monocytogenes* numbers on franks or ham by < 1 log unit.**

2. **5% lactic acid or 0.5% Na lauryl sulphate reduced numbers of *L. monocytogenes* on franks by 1 log unit; together they reduced numbers 1.5 log unit**

1. Fabrizio & Cutter, 2005. Meat Sci 71 (2), 327-333.
2. Byelashov et al., 2008. J. Food Prot (4), 728-734.

Conclusions

- Prevention is better than decontamination.
- Antimicrobial solutions will give reductions of <2 log units.
- Effects of treatments with two or more antimicrobial solutions will not be additive.
- Heating or irradiation treatments can give any required reduction, provided the treatment time is practicable and the effects on product quality are acceptable
- Combinations of physical and antimicrobial treatments can be additive.