

***Listeria monocytogenes***

**AND**

**LISTERIOSIS**

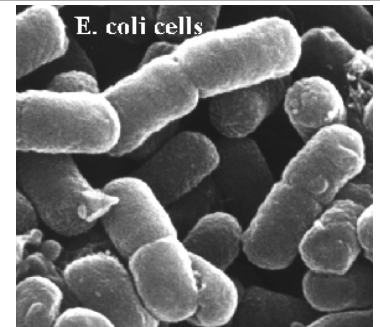
**John N. Sofos**

**John.Sofos@colostate.edu**



# Foodborne Illness in the United States

- **Illnesses per year: 75,814,924**
- **Hospitalizations: 323,854**
- **Deaths: 5,209**
- **Costs: \$8.4 Billion**



Mead et al. (1999)  
 CDC (1999)

<b>Pathogen</b>	<b>Illnesses</b>	<b>Fatality (%)</b>	<b>Deaths</b>
<i>Campylobacter</i>	2,453,926	<0.05	124
<i>Salmonella</i>	1,413,322	<0.05	585
<i>Escherichia coli</i> O157:H7	73,480	0.1	61
<i>Listeria monocytogenes</i>	2,518	20	504

# U.S.A. NATIONAL HEALTH OBJECTIVES FOR 2010

## Incidence of Foodborne Illnesses (*per 100,000 population*)

Pathogen	1996	2002	2003	2004	2005	Target 2010
<i>Campylobacter</i>	23.5	13.37	12.6	12.9	12.7	12.3
<i>Salmonella</i>	14.5	16.10	14.5	14.7	14.6	6.8
<i>L. monocytogenes</i>	0.50	0.27	0.33	0.27	0.30	0.25
<i>E. coli</i> O157:H7	2.7	1.73	1.1	0.9	1.06	1.0
SITES	5	9	9	10	10	
POPULATION	14.2M	37.5M	41.5M	44.1M	44.47	

CDC, FoodNet-Final Report, 1998 / CDC Preliminary FoodNet *Data*, 2005

# HISTORY OF *LISTERIA MONOCYTOGENES*

- **1918:** Isolated from cerebrospinal fluid (WWI soldier); meningitis; identified as *L. monocytogenes* (1940)
- **1926:** Sudden death of young rabbits; mononuclear leucocytosis; documented isolation (Murray et al.): *Bacterium monocytogenes*
- **1927:** Unusual death of gerbils, Johannesburg, South Africa; Tiger River Disease; *Listeria hepatolytica* (Lord Lister)
- **1929:** Human pathogen; *Listerella monocytogenes*
- **1940:** Named *Listeria monocytogenes*; *Listerella* had been used for a mold in honor of brother Arthur and father Joseph Lister; many other names; cause of Queen Ann's 17 miscarriages in 17<sup>th</sup> century?
- **1979:** Recognized as emerging foodborne pathogen

# HISTORY OF *LISTERIA MONOCYTOGENES*



- **Foodborne pathogen**
  - 1980-1981: Canada (coleslaw)
  - 1985: Los Angeles county, CA (Mexican-style soft cheese)
- **Case fatality rate: 20-30%**
- **Infectious dose (food matrix ↔ virulence ↔ host)**
  - Not a single infectious dose
  - Exposure concentration + subtype
  - $>10^2$  cells/g
- **FoodNet (2005): 3.0 cases/Million people**



# **LISTERIA MONOCYTOGENES AND LISTERIOSIS**



- **Widespread occurrence**
- **Sources:** soil, vegetation, silage, sewage, humans, animals, water, etc
- **Serious pathogen**
- **Low incidence of illness**
- **High risk groups:**
  - Pregnant women, neonates, immuno-deficient, cancer patients, organ transplant recipients, HIV infected, immunosuppressive therapy, advanced age
- **Foodborne: 99% of cases**
- **Other: animal-human; aerosols**

# ***LISTERIA MONOCYTOGENES*** ***AND LISTERIOSIS***



- **Illness:** infection; severe syndromes in sensitive individuals
- **Incubation Period:** 7 to 60 d
- **Duration of illness:** short to long
- **Mostly cases sporadic or clusters;** some outbreaks
- **Noninvasive gastrointestinal:** mild, flu-like, not well characterized
- **Invasive:** abortion, stillbirth, septicemia, sepsis, meningitis, meningoencephalitis, bacteremia, endocarditis, endophthalmitis, septic arthritis, osteomyelitis, pleural infection, peritonitis

# ***LISTERIA MONOCYTOGENES*** **AND LISTERIOSIS**



- **Infection of pregnant women:** flu-like illness; crosses placenta; attacks fetus; abortion, stillbirth or acutely ill baby; most common in third trimester
- **Perinatal 27%; Nonperinatal 70%**
- **Dietary Risk Factors:** deli foods, non-reheated hotdogs, luncheon meats, soft cheeses, coleslaw, unpasteurized milk,, ice cream, vegetables, seafood, antacids, laxatives
- **Control:** sanitation, hygiene, proper cooking, prevent cross- or re-contamination, post-processing interventions



# Outbreaks of Listeriosis

Location (Year)	# Cases (Deaths)	Perinatal/ Non-perinatal	Foods Associated	Serotype
Boston, US (1979)	20 (5)	0/20	Raw celery, tomatoes, lettuce	4b most 1/2b
New Zealand (1980)	29 (9)	22/7	Shellfish, raw fish	4b
CAN (1981)	41 (17)	34/7	Coleslaw mix	4b
MA, US (1983)	49 (14)	7/42	Pasteurized milk	4b
CA, US (1985)	142 (48)	93/49	Jalisco cheese	4b
Switzerland (1983-1987)	122 (31)	65/57	Raw milk cheese	4b, 1/2a,
PA, US (1986-1987)	36 (16)	4/32	Ice cream, salami	1/2b,3b
CT, US (1989)	9 (1)	2/7	Shrimp	4b
UK (1987-89)	355 (94)	185/129	Pate	4b

Farber and Peterkin (2000)

# Outbreaks of Listeriosis

Location (Year)	# Cases (Deaths)	Perinatal/ Non-perinatal	Foods Associated	Serotype
W Australia (1990)	11(6)	11/0	Pate	1/2a
Tasmania (1991)	4	0/4	Smoked mussels	1/2
New Zealand (1992)	4(2)	4/0	Smoked mussels	1/2
France (1993)	39 (12)	31/8	Pork rillettes (pate)	4b
France (1992)	279 (85)	92/187	Pork tongue in jelly	4b
Italy (1993)	23 (0)	0/23	Rice salad	1/2b
Texas, US (1993-1994)	8 (1)	4/4	Frozen mixed vegs	4b
US (1994)	45 (0)	1/44	Chocolate milk (1%)	1/2b
France (1995)	20 (4)	11/9	Raw milk soft cheese	4b
Sweden (1994-1995)	6 (1)	2/4	Cold-smoked Trout	4b
US (1998-2002)	100 (21)		Luncheon meats	4b

Farber and Peterkin (2000)

# Incidence of Listeriosis in Humans

## Groups

## Order of Risk

**Organ Transplant Recipients**

**1**

**AIDS Patients**

**2**

**HIV-Infected**

**3**

**Pregnant Women**

**4**

**Cancer Patients**

**5**

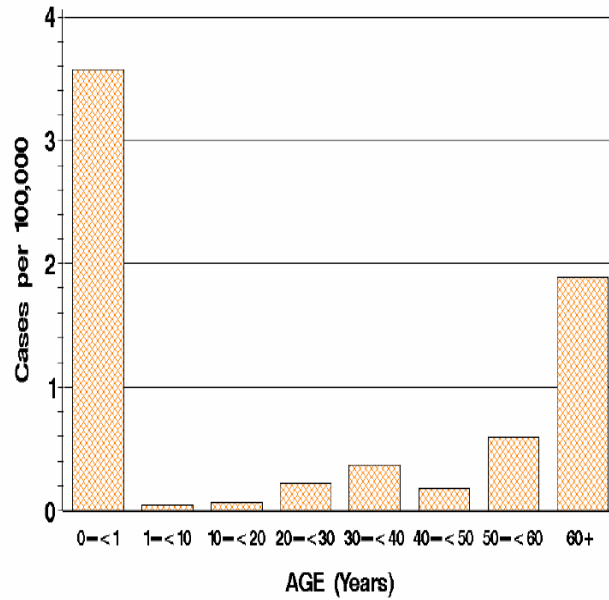
**Over Age 65**

**6**

Rocourt (1996)

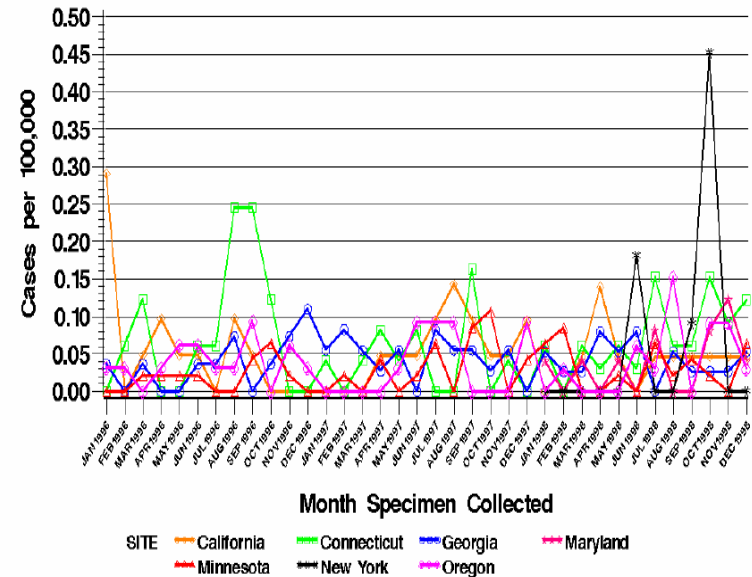
## CDC's Emerging Infections Program

CDC/USDA/FDA Foodborne Diseases Active Surveillance Network (FoodNet)  
 Cases per 100,000 Postcensal Population Estimates Age Distribution by Pathogen for All Sites  
 FoodNet 1998 Final Report  
 Pathogen = LISTERIA



## CDC's Emerging Infections Program

CDC/USDA/FDA Foodborne Diseases Active Surveillance Network (FoodNet)  
 Rate per 100,000 per Month Postcensal Population Estimates  
 Pathogen = LISTERIA



9/9/98

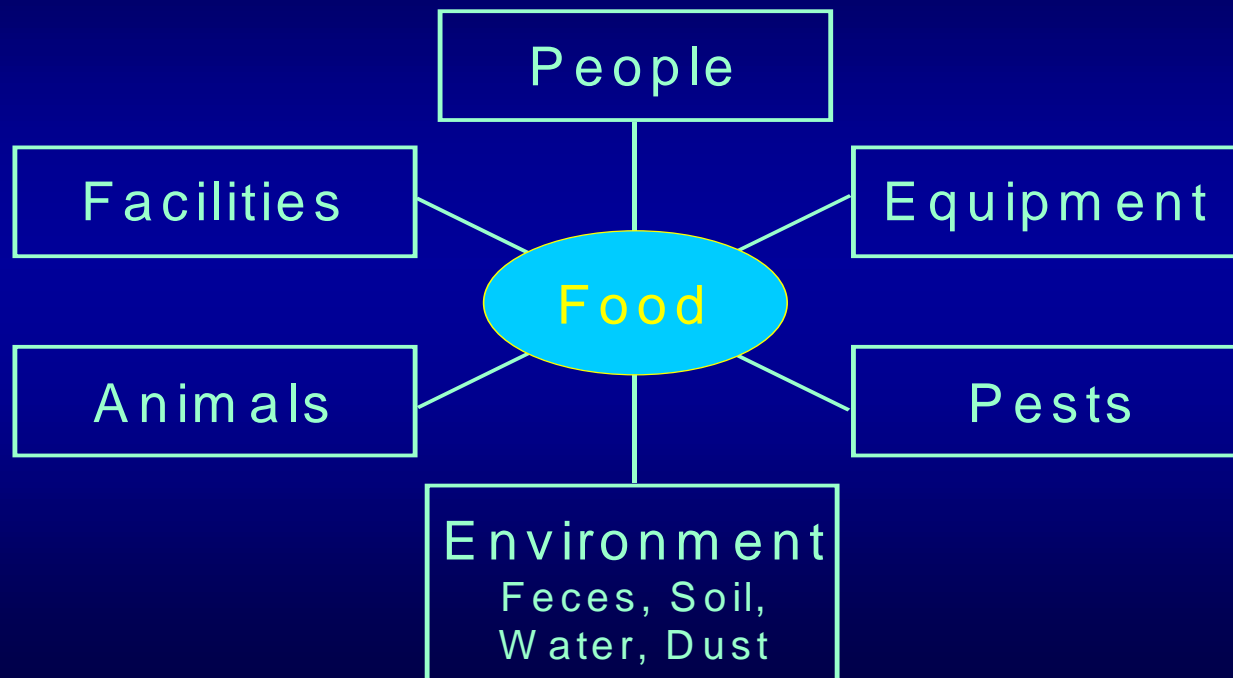
# Fecal Carriage Rates of *Listeria monocytogenes*

Human Population	Tested (#)	Positive (%)
● Slaughterhouse Workers	1147	4.8
● Listeriosis Household Contacts	341	26
● Laboratory Workers	26	77
● Office Workers	26	62
● Healthy Food Handlers	2000	0.8
● Renal Transplant Patients	177	5.6
● Pregnant Women with Listeriosis	18	5.6
● Healthy Pregnant Women	147	2.7
● Cheese Plant Employees	31	9.7

Slutsker and Schuchat (1999)

# MICROBIAL COMMUNITY

## SOURCES OF MICROBIAL CONTAMINATION

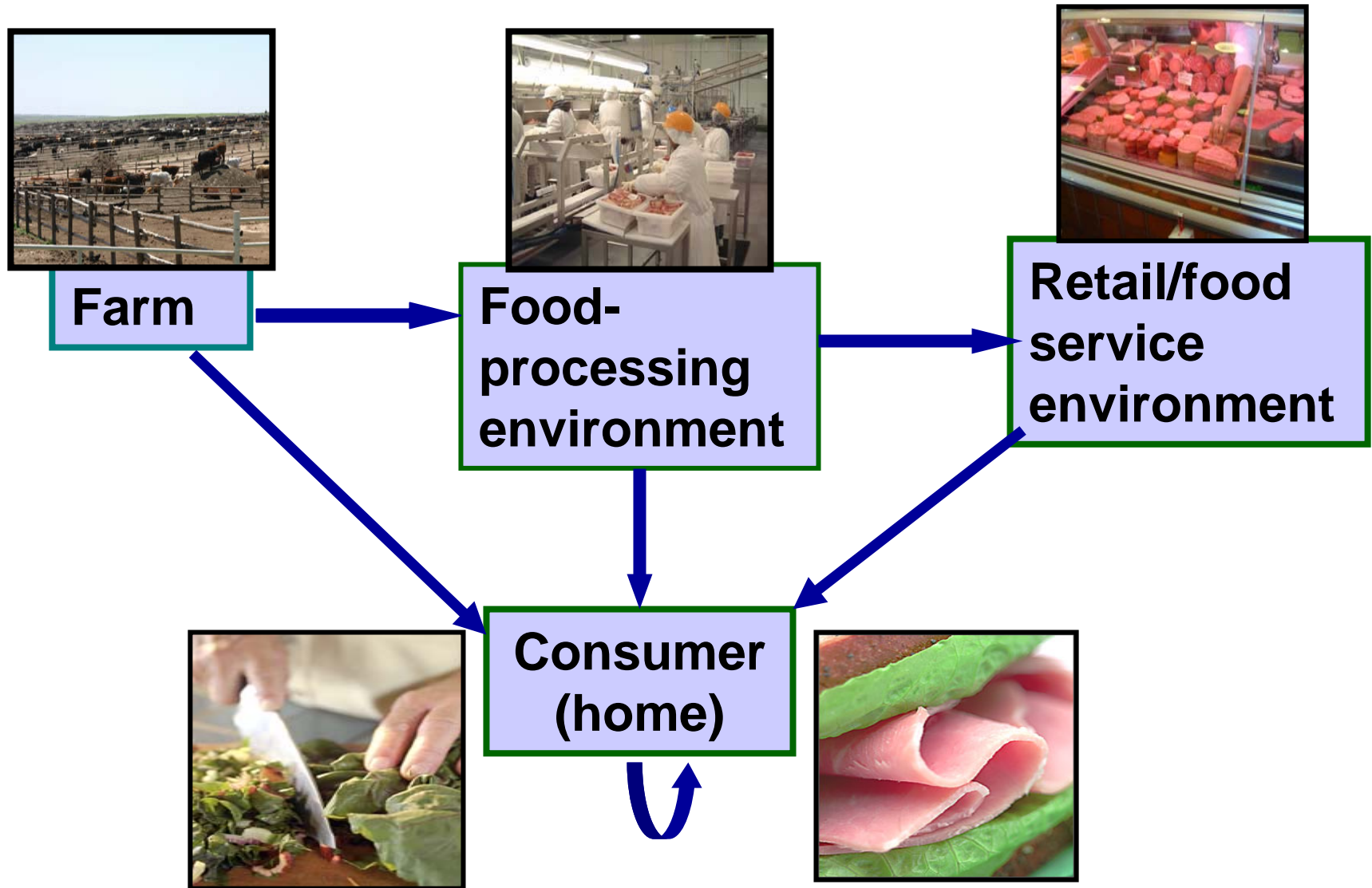


# ***LISTERIA MONOCYTOGENES* SOURCES**

- ➡ **Natural habitat:** soil, water, sewage, decaying vegetation, silage
- ➡ **Survival in adverse environments:** better than other nonspore-formers
- ➡ **Plant environment:** can colonize, multiply and persist; attach and form biofilms
- ➡ **Environmental sources:** drains, conveyor belts, floor mats, foot baths, freezers, coolers, equipment, chilling rooms, cutting rooms, hands, packaging
- ➡ **Stress (acid, cold and starvation) adaptation:** hardening; cross-protection; resistance
- ➡ **Major Concern:** post-processing contamination



# LISTERIA MONOCYTOGENES CHAIN





# SURVIVAL OF *LISTERIA MONOCYTOGENES* IN THE ENVIRONMENT

<u>SUBSTRATE</u>	<u>TEMPERATURE (°C)</u>	<u>DAYS</u>
<b>Soil</b>	<b>4-6</b>	<b>12 to &gt;730</b>
<b>Water</b>	<b>2-37</b>	<b>&lt;7 to 928</b>
<b>Animal feed</b>	<b>4 to 22</b>	<b>23 to 2190</b>
<b>Fecal material</b>	<b>5 to 56</b>	<b>35 to 2190</b>

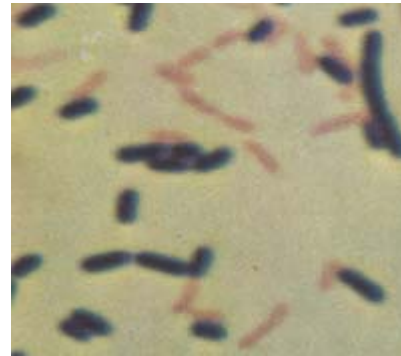


TABLE 2. Examples demonstrating that certain strains of *L. monocytogenes* can become established and persist in the food-processing environment

Type of food produced at plant	Time of persistence <sup>a</sup>	Country	Implicated in illness?	Serotype(s) <sup>b</sup>	Reference(s)
Cheese	4 years	Switzerland	Yes	4b	5
Cheese, blue veined	7 years	Sweden	No	3b	94
Cheese, goat	11 months	United Kingdom	Yes	4b	3, 63
Fish, smoked	Months	Switzerland	No	Several	6
	14 months	Finland	No	1/2a (86%), 4b (14%)	53
	Months	United States	No	ND	70
Frankfurters	4 months	United States	Yes	1/2a	16, 95
Frankfurters (outbreak strain was not isolated from the plant)	Months	United States	Yes	4b	17
Ice cream	7 years	Finland	No	1/2	66
Meat, sliced lunch	4 years	Norway	No	ND	69
Mussels, smoked	3 years	New Zealand	Yes	1/2	7
Pâté (product from one plant was the source of an outbreak from 1987 to mid-1989)	2 years	United Kingdom	Yes	4b(x), 4b	64, 72
Pork tongue in aspic (outbreak strain recovered from the implicated plant)	Months	France	Yes	4b	50, 86
Poultry, cooked	1 year	Ireland	No	1/2	57
Poultry, cooked deli products (outbreak strain matched a strain previously isolated from the same plant (95))	12 years	United States	Yes	4b	89
Salmon, cold smoked	4 years	Denmark	No	ND	31
Salmon, smoked	8 months	Norway	No	ND	82
Seafood, smoked salmon	Months–2 years	Norway	Possibly	4, 1	81
Shrimp, raw shelled frozen	NS	Brazil	No	1, 4b	25
Trout/salmon, gravad	1 month	Sweden	No	4b	60
Trout, gravad and cold smoked	11 months	Sweden	Yes (gravad)	4b	28
Trout, smoked/salmon, gravad	>4 years	Sweden	Possibly	1/2a	59
Trout, cold smoked	NS	Finland	No	1/2	2

<sup>a</sup> NS, not stated.

<sup>b</sup> ND, not determined.



## PERSISTENCE IN PLANT ENVIRONMENTS

J. Food Prot., Vol. 65, No. 4

# MAJOR LISTERIOSIS OUTBREAKS and RECALLS

## FRANKFURTERS/LUNCHEON MEAT, 1998-1999:

■ 108 cases; 18 deaths (4 stillbirths/miscarriages); 24 states

## DELI POULTRY PRODUCTS, 2000:

■ 29 cases; 7 deaths (3 miscarriages); 10 states

## DELI POULTRY PRODUCTS, 2002:

■ 46 cases; 10 deaths (3 miscarriages/stillbirths); 8 states

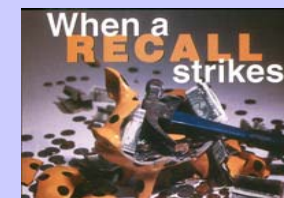


## TOP THREE USA MEAT/POULTRY RECALLS

Hot dogs/packaged meats: 17M Kg; 12/22/1998

Various rte products: 17M Kg; 1/22/1999

Fresh and frozen rte poultry products: 13M Kg; 10/12/2002,  
Company A (Drain); 2M Kg; 11/2/2002, Company B (Product)



# Prevalence of *Listeria monocytogenes* in Ready-to-Eat Meat Products (1990-1997)

## Country

USA

Canada

UK

Denmark

Italy

Australia



## *L. monocytogenes* (% +)

8 to 71

0 to 21

2 to 35

6 to 23

2 to 60

0 to 72

(Various Sources)

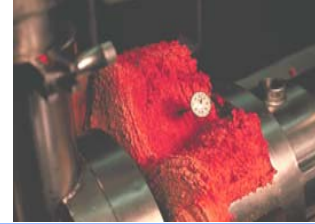
# USA INCIDENCE OF *LISTERIA MONOCYTOGENES*

<b>YEAR</b>	<b>POSITIVE (%)</b>
<b>2003</b>	<b>0.75</b>
<b>2002</b>	<b>1.03</b>
<b>2001</b>	<b>1.32</b>
<b>2000</b>	<b>1.45</b>
<b>1999</b>	<b>1.91</b>
<b>1998</b>	<b>2.54</b>
<b>1997</b>	<b>2.25</b>
<b>1996</b>	<b>2.91</b>
<b>1995</b>	<b>3.03</b>

USDA/FSIS DATA: RTE MEAT PRODUCTS; 7,500 SAMPLES/YEAR

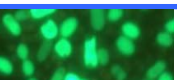


# USA INCIDENCE OF *LISTERIA MONOCYTOGENES*



Product	Number positive in CFU/g Range					
	0.04-0.1		>0.1-10 <sup>2</sup>		>10 <sup>2</sup>	
	CA	MD	CA	MD	CA	MD
Fresh soft cheeses	0	2	1	2	0	0
Bagged salads	12	5	2	2	0	1
Blue cheeses	13	5	4	1	0	0
Mold cheeses	11	1	2	0	0	0
Seafood salads	26	56	1	30	0	0
Smoked seafood	44	23	21	17	6	3
Luncheon meats	10	32	15	17	3	5
Deli salads	78	84	20	19	1	3

Gombas et al. 2003





# *Listeria monocytogenes* at Retail

- Eight RTE food categories (2000-2001)
- Overall prevalence: 1.82% (0.17-4.7%)
- Sliced luncheon meats: 0.89%
- Contamination levels
  - Majority of positive samples: <10 CFU/g
  - Luncheon meats and smoked seafood (>10<sup>2</sup> CFU/g)
- In-store vs. manufacturer packaged samples
  - *Higher prevalence* in in-store-packaged products
  - *Higher levels* in manufacturer-packaged products



Gombas et al., 2003

# Consumer Food-handling Practices

- **Cross-contamination**
- **Temperature control**
- **Time lapse between retail and home refrigeration**
- **Refrigeration temperature**
  - **27% of home refrigerators contained product at temperatures  $>41^{\circ}\text{F}$**
- **Home storage time length (extended storage)**





**Summary Table 4. Relative Risk Ranking and Predicted Median Cases of Listeriosis for the Total United States Population on a per Serving and per Annum Basis**

Relative Risk Ranking	Predicted Median Cases of Listeriosis for 23 Food Categories					
	Per Serving Basis <sup>a</sup>			Per Annum Basis <sup>b</sup>		
	Food	Cases		Food	Cases	
1	High Risk	Deli Meats	7.7x10 <sup>-8</sup>	Very High	Deli Meats	1598.7
2		Frankfurters, not reheated	6.5x10 <sup>-8</sup>	High Risk	Pasteurized Fluid Milk	90.8
3		Pâté and Meat Spreads	3.2x10 <sup>-8</sup>		High Fat and Other Dairy Products	56.4
4		Unpasteurized Fluid Milk	7.1x10 <sup>-9</sup>		Frankfurters, not reheated	30.5
5		Smoked Seafood	6.2x10 <sup>-9</sup>	Moderate Risk	Soft Unripened Cheese	7.7
6		Cooked Ready-to-Eat Crustaceans	5.1x10 <sup>-9</sup>		Pâté and Meat Spreads	3.8
7	Moderate Risk	High Fat and Other Dairy Products	2.7x10 <sup>-9</sup>		Unpasteurized Fluid Milk	3.1
8		Soft Unripened Cheese	1.8x10 <sup>-9</sup>		Cooked Ready-to-Eat Crustaceans	2.8
9		Pasteurized Fluid Milk	1.0x10 <sup>-9</sup>		Smoked Seafood	1.3
10	Low Risk	Fresh Soft Cheese	1.7x10 <sup>-10</sup>	Low Risk	Fruits	0.9
11		Frankfurters, reheated	6.3x10 <sup>-11</sup>		Frankfurters, reheated	0.4
12		Preserved Fish	2.3x10 <sup>-11</sup>		Vegetables	0.2
13		Raw Seafood	2.0x10 <sup>-11</sup>		Dry/Semi-dry Fermented Sausages	<0.1
14		Fruits	1.9x10 <sup>-11</sup>		Fresh Soft Cheese	<0.1
15		Dry/Semi-dry Fermented Sausages	1.7x10 <sup>-11</sup>		Semi-Soft Cheese	<0.1
16		Semi-soft Cheese	6.5x10 <sup>-12</sup>		Soft Ripened Cheese	<0.1
17		Soft Ripened Cheese	5.1x10 <sup>-12</sup>		Deli-type Salads	<0.1
18		Vegetables	2.8x10 <sup>-12</sup>		Raw Seafood	<0.1
19		Deli-type Salads	5.6x10 <sup>-13</sup>		Preserved Fish	<0.1
20		Ice Cream and Other Frozen Dairy Products	4.9x10 <sup>-14</sup>		Ice Cream and Other Frozen Dairy Products	<0.1
21		Processed Cheese	4.2x10 <sup>-14</sup>		Processed Cheese	<0.1
22		Cultured Milk Products	3.2x10 <sup>-14</sup>		Cultured Milk Products	<0.1
23		Hard Cheese	4.5x10 <sup>-15</sup>		Hard Cheese	<0.1

<sup>a</sup>Food categories were classified as high risk (>5 cases per billion servings), moderate risk (≤5 but ≥1 case per billion servings), and low risk (<1 case per billion servings).

<sup>b</sup>Food categories were classified as very high risk (>100 cases per annum), high risk (>10 to 100 cases per annum), moderate risk (≥1 to 10 cases per annum), and low risk (<1 cases per annum).

## RISK RANKING

### Interpretive Summary:

**Quantitative Assessment of the Relative Risk to Public Health from Foodborne *Listeria monocytogenes* Among Selected Categories of Ready-to-Eat Foods**

Center for Food Safety and Applied Nutrition  
Food and Drug Administration  
U.S. Department of Health and Human Services

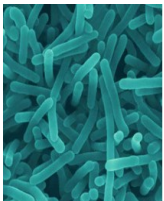
Food Safety and Inspection Service  
U.S. Department of Agriculture  
September 2003



# ***LISTERIA MONOCYTOGENES* USA RISK ASSESSMENT**

## **Factors affecting health impact of listeriosis:**

- Amount and frequency of RTE food consumption**
- Frequency and level of contamination**
- Potential of food to support growth at refrigeration**
- Refrigerated storage temperature**
- Refrigerated storage duration**



# ***LISTERIA MONOCYTOGENES* USA RISK ASSESSMENT**

## **Conclusions based on risk assessment:**

- Listeriosis is rare/declining**
- Controlling growth in RTE foods is “the key” to preventing listeriosis**
- Practices to reduce risk by 50%:**
  - ▣ Refrigerate foods below 4°C (40°F)**
  - ▣ Use RTE perishable foods as soon as possible**
  - ▣ Or, reformulate products to inhibit growth**





# ***LISTERIA MONOCYTOGENES USA*** **RISK ASSESSMENT**

## **Advice for pregnant women/sensitive people:**

- Do not eat hot dogs and luncheon meats; reheat**
- Do not eat soft cheeses unless made with pasteurized milk**
- Do not eat refrigerated pates or meat spreads; canned may be eaten**
- Do not eat refrigerated smoked seafood, unless in a cooked casserole; eat shelf-stable seafood**
- Do not drink unpasteurized milk nor eat foods that contain unpasteurized milk**



Friday,  
June 6, 2003

Part V

Department of  
Agriculture

Food Safety and Inspection Service

9 CFR Part 430  
Control of *Listeria monocytogenes* in  
Ready-to-Eat Meat and Poultry Products;  
Final Rule

## ● Post-lethality alternatives:

- (1) a. Treatment (may be antimicrobial agent) that reduces or eliminates microorganisms, **AND**
  - b. Antimicrobial agent/process that inhibits growth
- (2) a **OR** b (*more FSIS verification*)
- (3) Sanitation and microbiological testing programs (*more...more FSIS verification*)

Fed. Reg.: June 6, 2003; Vol. 68, N# 109; Pp. 34207-34254; 9 CFR Part 430

# Conditions Affecting Growth of *Listeria monocytogenes*

Condition	Minimum	Maximum
Temperature (°C)	0	45
Acidity (pH)	4.3 to 5.7	9.6
Water Activity ( $a_w$ )	0.90 to 0.94	---
Gases (CO <sub>2</sub> )	50	---
Sodium chloride (% w/v)	≤10 growth	>10 survival

*Salt & Acidity: survival temperature dependent*

*Minimum Temperature: affected by food/other factors; survives frozen storage*



# INDUSTRY CONTROLS FOR *LISTERIA*



- Proper risk and hazard analysis
- Manage supplier quality
- Environmental sampling/testing/monitoring
- Effective and documented sanitation/prevent niches
- Good manufacturing practices (GMP) and HACCP
- Proper and effective worker training/SOP
- Upgrade older plants (drains, traffic, etc)
- Control rework and product reprocessing
- Effective product lotting/limit the size of product lots
- Effective coding and traceability/recall plans
- Use lethal processes (steam, hot water, pressure, etc)
- Use chemicals
- Use combinations
- Proper validation, verification and documentation



# CONSUMER EDUCATION FOR CONTROL OF LISTERIOSIS

- Thorough cooking of animal foods
- Thorough washing of raw vegetables
- Separation of uncooked from ready-to-eat foods
- Washing hands, cutting boards, knives, etc.
- At-risk individuals:
  - Avoid or cook risky foods
  - Avoid raw/unpasteurized foods
  - Do not store risky food for a long time

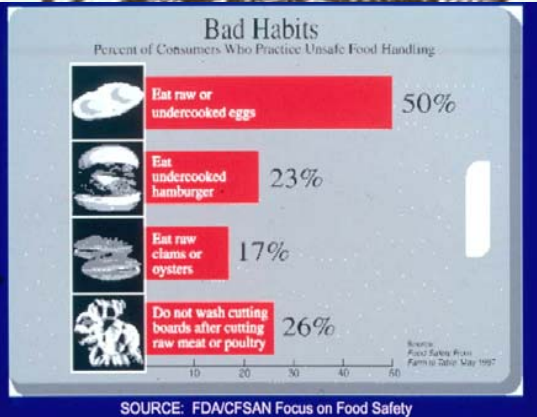




# CONSUMER AND FOOD HANDLER EDUCATION: Most foodborne illness due to mishandling of foods in ways we know we should avoid

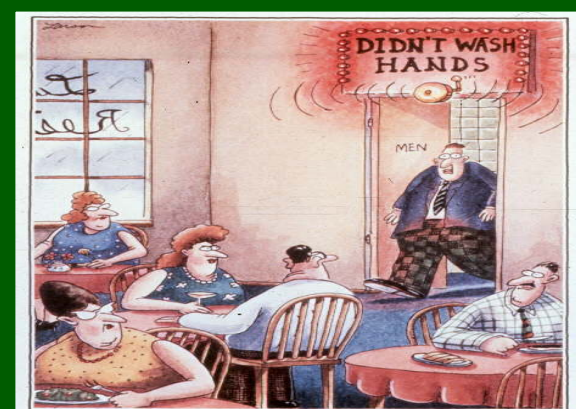
## ULTIMATE FOOD SAFETY SYSTEM

**KEEP it CLEAN and COVERED**  
**KEEP it COLD or HOT**  
**KEEP it MOVING**



### WHAT'S IT DO TO THE MEAT?

IT COOKS IT.



**TEMPERATURE DANGER ZONE**  
**40 to 140 °F**  
**(4.4 to 60.0 °C)**

BOB BLISS