

Appendix 8:
Growth of *Listeria monocytogenes* in Foods

Appendix 8 Table 1: Growth Rate of *Listeria monocytogenes* in Food Categories Considered for this Risk Assessment Growth Product -

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
SEAFOOD				
Smoked Seafood				
Duffes <i>et al.</i> , 1999	cold-smoked salmon	4 °C	2.1 logs in 28 days	0.107
		8 °C	5.4 logs in 21 days	0.116
		4 °C	2.0 logs in 21 days	0.136
		8 °C	4.6 logs in 14 days	0.149
Jemmi and Keusch, 1992	hot-smoked trout	4 °C	0.5 logs in 20 days	0.035
		8 to 10 °C	6.5 logs in 20 days	0.120
Hudson and Mott, 1993b	cold-smoked salmon	5 °C	4 logs in 650 hours	0.148
		10 °C	4 to 4.5 logs in 125 hours	0.249
Szabo and Cahill, 1999	smoked salmon	4 °C	3.9 logs in 28 days	0.198
		10 °C	2.7 to 4.3 logs in 9 days	0.119
Dillon and Patel, 1993	cold-smoked cod	4 °C	2.8 logs in 21 days	0.190
Guyer and Jemmi, 1991	smoked salmon (26 to 30 °C)	4 °C	1.0 to 1.5 logs in 10 days	0.177
		10 °C	3 to 3.5 logs in 10 days	0.099
Pelroy <i>et al.</i> , 1994b	cold-smoked salmon	5 °C	2.5 to 5 logs in 40 days	0.092
		5 °C	2 logs in 40 days	0.050
		10 °C	4.5 to 7 logs in 10 days	0.249
		10 °C	5 logs in 11 days	0.139
Pelroy <i>et al.</i> , 1994a	cold-smoked salmon	5 °C	4 logs in 50 days	0.080
		10 °C	4.5 logs in 15 days	0.092
Peterson <i>et al.</i> , 1993	cold-smoked salmon	5 °C	3 logs in 20 days	0.150
		5 °C	2.5 logs in 20 days	0.125
		10 °C	4 logs in 7 days	0.175
		10 °C	3.7 logs in 7 days	0.162
		10 °C	6 logs in 20 days	0.092
Rosso <i>et al.</i> , 1996	smoked salmon	4 °C	1 log in 10 days	0.142
		8 °C	3 logs in 14 days	0.097
Nilsson <i>et al.</i> , 1997	cold-smoked salmon	5 °C	5 logs in 9 days	0.556
Raw Seafood				
Fernandes <i>et al.</i> , 1998	fresh trout	4 °C	1 logs in 15 days	0.100
		4 °C	2 logs in 15 days	0.185
Lovett <i>et al.</i> , 1990	raw shrimp, crab, surimi and whitefish	7 °C	GT in 12 hours	0.342
Kaysner <i>et al.</i> , 1990	raw oysters	4 °C	No growth in 21 days	0.000
Leung <i>et al.</i> , 1992	catfish	4 °C	1-1.5 logs in 12 days	0.133
Shineman and Harrison, 1994	raw shrimp and fin fish	ice chest	No growth [1 log decrease in 21 days]	—

^alogs = Log₁₀ cfu/g

^bGT = Generation Time

^cEGR = Exponential Growth Rate

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C
		Temperature	Growth Rate ^{a,b}	(log ₁₀ cfu/day)
Raw Seafood (Cont'd)				
Harrison <i>et al.</i> , 1991	raw shrimp and fin fish	ice chest	No growth [0.5 log decrease in 14 days]	—
Preserved Fish				
No data available			No growth	0.000 used in risk assessment
Cooked Ready-to-Eat Crustaceans				
Rawles <i>et al.</i> , 1995	pasteurized crab	5 °C	GT in 21.8 hours	0.343
Farber, 1991b	cooked lobster, shrimp, crab and smoked fish	4 °C	2-3 logs in 7 days	0.508
Buchanan and Klawitter, 1992	pasteurized crabmeat	5 °C	3 logs in 10 days	0.300
PRODUCE				
Vegetables				
Steinbrugge <i>et al.</i> , 1988	lettuce, whole, ready to serve	5 °C	0.00 to 0.3 logs in 7 days	0.043
		12 °C	0.00 to 2.03 logs in 7 days	0.004
	lettuce, whole, ready to serve, sealed	25 °C	0.00 to 0.31 logs in 7 days	0.002
Beuchat and Brackett, 1990b	lettuce, shredded	5 °C	0.00 to 0.1 logs in 15 days	0.007
		10 °C	1.5-2.0 logs in 3 days	0.204
	lettuce, whole	10 °C	1.0 logs in 15 days	0.067
Nguyen and Carlin, 1994	lettuce, butterhead	10 °C	1.5 logs in 7 days	0.065
Nguyen and Carlin, 1994	lettuce, lamb's	10 °C	1.0 logs decrease in 7 days	-0.044
Francis and O'Beirne, 2001	lettuce	8 °C	1.5 logs in 7 days	0.097
Carlin <i>et al.</i> , 1996	endive, broad leaved	10 °C	1.0 logs in 7 days	0.044
Nguyen and Carlin, 1994	endive, broad leaved	10 °C	1.5 logs in 7 days	0.065
Nguyen and Carlin, 1994	endive, curly-leaved	10 °C	0.5 logs in 7 days	0.022
Beuchat and Brackett, 1991	tomatoes	10 °C	no growth (death in chopped tomatoes)	0.00
		21 °C	Growth	—

^aLogs = Log₁₀ cfu/g

^bGT = Generation Time

^cEGR = Exponential Growth Rate

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Vegetables (Cont'd)				
Castillego Rodriguez <i>et al.</i> , 2000	Asparagus	4 °C	0.0087 log decrease per hour	-0.09
		8 °C	0.038 logs per hour	0.413
Beuchat and Brackett, 1990a	carrots, whole and shredded	5 °C	no growth up to 7 days	0.00
		15 °C	no growth up to 7 days	0.00
Beuchat <i>et al.</i> , 1986	cabbage, raw, shreds	5 °C	4 logs in 10 days	0.400
Berrang <i>et al.</i> , 1989	Broccoli	4 °C	0.25 to 0.5 logs in 14 to 21 days	0.059
		15 °C	3.0 logs in 4 days	0.109
Berrang <i>et al.</i> , 1989	Cauliflower	4 °C	≤ 0.25 logs in 14 to 21 days	0.020
		15 °C	3.0 logs in 4 days	0.109
Francis and O'Beirne, 2001	Rutabaga	8 °C	1.75 logs in 12 days	0.066
Francis and O'Beirne, 2001	Bean sprout	8 °C	1.75 logs in 8 days	0.099
Sizmur and Walker, 1988	salads, mixed , prepacked including fruits/nuts	4 °C	0.30 logs in 4 days	0.106
Fruits				
Parish and Higgins, 1989	orange, serum (juice)	4 °C	1.0 logs in 35 days (pH 5.0)	0.041
Conway <i>et al.</i> , 2000	Apple slices (fresh cut)	5 °C	0 logs in 6 days	0
		10 °C	2 logs in 6 days	0.102 (air)
Conway <i>et al.</i> , 2000	Apple slices (fresh cut)	5 °C	0 logs in 4 days	0
		10 °C	2.8 logs in 10 days	0.086 (0.5% O ₂ , 15% CO ₂)
DAIRY PRODUCTS				
Fresh Soft Cheese				
Glass <i>et al.</i> , 1995	Queso blanco	4 °C	1.4 logs in 14 days	0.142
Mendoza-Yepes <i>et al.</i> , 1999	Queso fresco	3 °C	0.13 log in 1 day	0.284
		7 °C	0.5 log in 1 day	0.285
Genigeorgis <i>et al.</i> , 1991	Queso fresco, Queso Ranchero Queso Panella	4 °C	-2.0 logs in 30 days	-0.067
			-0.8 logs in 10 days	-0.080
			0.3 logs in 30 days	0.010
			0.3 logs in 18 days	0.017
			2.127 logs in 10 days	0.212
			0.21 logs in 30 days	0.007
0.44 logs in 36 days	0.012			

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Soft Unripened Cheese				
Genigeorgis <i>et al.</i> , 1991	cottage cheese (multiple brands)	8 °C	0.59 logs in 18 days	0.015
			1.87 decrease in 36 days	-0.024
		4 °C	0.42 logs in 24 days	0.007
			1.13 logs in 8 days	0.064
			1.87 decrease in 8 days	-0.106
			0.39 logs in 24 days	0.023
	teleme cheese	8 °C	2.2 logs in 36 days	0.028
		4 °C	0.42 logs decrease in 36 days	-0.017
	ricotta (3 company brands)	8 °C	2.11 logs in 8 days	0.120
			1.75 logs in 6 days	0.132
		4 °C	1.88 logs in 8 days	0.106
			1.53 logs in 30 days	0.072
	cream cheese	8 °C	3.58 logs in 36 days	0.141
		4 °C	1.97 logs in 22 days	0.127
2.0 logs decrease in 30 days			-0.030	
Cottin <i>et al.</i> , 1990	cream cheese	4 °C	2 logs in 2 days	1.423
Papageorgiou <i>et al.</i> , 1996	ricotta (whey cheese)	5 °C	16.2 – 20.2 hr in GT	0.397
		12 °C	5.1 – 5.8 hr in GT	0.292
Chen and Hotchkiss, 1993	cottage cheese	4 °C	2.0 logs in 40 days	0.071
		7 °C	2.4 logs in 10 days	0.137
Fedio <i>et al.</i> , 1994	cottage cheese	5 °C	2 logs in 22 days	0.091
El-Shenawy and Marth, 1990	cottage cheese	refrigerated	0.5 to 1.5 logs decrease in 1 to 5 weeks	-0.048
		6 °C	assume 1 log in 21 days	-0.035

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Soft Ripened Cheese				
Papageorgiou and Marth, 1989b	Feta	4 °C	survival > 90 days [Scott A 1.28 logs decrease, 3.07 logs in 90 days]	0 -0.034
Stecchini <i>et al.</i> , 1995	mozzarella	5 °C	4 logs in 21 days	0.190
Genigeorgis <i>et al.</i> , 1991	Brie	4 °C	0.6 logs in 30 days 0.6 logs in 14 days	0.020 0.043
	Feta	4 °C	>2.0 logs decrease in 8 day >2.0 logs decrease in 8 days >2.0 logs decrease in 8 days	-0.250 -0.250 -0.250
Ryser and Marth, 1987b	Camembert	6 °C ripening	4 logs in 45 days	0.066
Farber <i>et al.</i> , 1987	Camembert	4 °C	2 to 3 longs decrease in 365 days	-0.007
Back <i>et al.</i> , 1993	Camembert	3°C	0.9 logs in 10 days	0.197
		6°C	1.5 logs in 15 days	0.074
		10C	2.4 logs in 15 days	0.049
Papageorgiou and Marth, 1989a	Blue cheese	5°C	Decreased during storage, 3 logs in 56 days	-0.054
Sulzer and Busse, 1993	Camembert Camembert (surface growth)	14 °C	4.5 logs in 34 days	0.022
		7 °C	—	—
		4 °C	—	—
				[Not used in risk assessment]
Genigeorgis <i>et al.</i> , 1991	Blue	4 °C	>2.0 logs decrease in 36 days	-0.056
Genigeorgis <i>et al.</i> , 1991	Camembert	4 °C	0.64 logs in 36 days	0.018
Semi-Soft Cheese				
Ryser and Marth, 1989a	Brick (surface ripened)	10 °C	1 to 7-fold decrease in 20 weeks	-0.043
Ryser and Marth, 1989a	tilsiter, trappist, havarti, limburger	10 °C	< 1 logs in 20 wk	0.015
Kovincic <i>et al.</i> , 1991	Trappist	10 °C	Initial 1 log during ripening, stable 30 days, 1 log decrease for 90 days	-0.011
Bachmann and Spahr, 1995	emmenthaler, tilster	—	no survival after 24 hours (initial level was 10 ⁴ cfu/g)	— [not used in risk assessment]
Northolt <i>et al.</i> , 1988	gouda	—	Survival 6 weeks	0.000

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Semi-Soft Cheese con't				
Genigeorgis <i>et al.</i> , 1991	Monterey Jack	4 °C	>2.1 logs decrease in 30 days > 2.1 logs decrease in 30 days	-0.070 -0.070
Genigeorgis <i>et al.</i> , 1991	Limburger	4 °C	2.26 logs decrease in 36 days	-0.064
Genigeorgis <i>et al.</i> , 1991	Provolone	4 °C	2.36 logs decrease in 36 days	-0.066
Genigeorgis <i>et al.</i> , 1991	String cheese	4 °C	2.29 logs decrease in 36 days	-0.064
Genigeorgis <i>et al.</i> , 1991	Muenster	4 °C	2.0 logs decrease in 36 days	-0.056
Hard Cheese				
Whitley <i>et al.</i> , 2000	Stilton cheese	4 °C (2 to 8.3°C reported)	0.7 log in 6 weeks	0.0285
Yousef and Marth, 1988	colby	4 °C	1.5 logs decrease in 100 days (after 40 days)	-0.053
Ryser and Marth, 1987a	cheddar	13 °C	2 logs decrease in 75 to 150 days	-0.003
Buazzi <i>et al.</i> , 1992	swiss	7 °C	4 logs decrease in 10 days (complete inactivation 66-80 days ripening at 24 °C)	-0.228
Yousef and Marth, 1990	parmesan	—	2.0 logs decrease in 40 days 2.0 logs decrease in 80 days	-0.048 -0.025
Genigeorgis <i>et al.</i> , 1991	swiss	4 °C	>2.1 logs decrease in 36 days	-0.058
Kaufmann, 1990	emmenthaler, gruyere	—	no survival after 24 hours (initial level was 10 ⁴ cfu/g)	— [not used in risk assessment]
Genigeorgis <i>et al.</i> , 1991	Cheddar, cracker barrel	4 °C	1.17 logs decrease in 34 days	-0.049
	Cheddar, mild	4 °C	>2.1 logs decrease in 30 days >2.1 logs decrease in 36 days	-0.070
	Cheddar, sharp	4 °C		-0.058
	Colby	4 °C	0.81 logs decrease in 36 days	-0.022
Processed Cheese				
Genigeorgis <i>et al.</i> , 1991	American process cheese	4 °C	0.18 logs decrease in 36 days 1.84 logs decrease in 36 days	-0.005 -0.051
	American process cheese with sorbate and citrate	4 °C		
	Piedmont process cheese	4 °C	1.62 logs decrease in 36 days	-0.045
Glass <i>et al.</i> , 1998	Pasteurized process cheese		0.6 logs decrease during 96 hours	-0.15
Ryser and Marth, 1989b	Cold pack cheese	3°C	0.5 logs decrease in 110 days	-0.004
	Non-acid		1.0 logs decrease in 60 days	
	Acidified or preservatives	3°C		-0.017

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Fluid Milk, Pasteurized and Unpasteurized				
Northolt <i>et al.</i> , 1988	unpasteurized milk	5 °C 7 °C	GT 3.5 in days GT 1.0 in days	0.085 0.173
Northolt <i>et al.</i> , 1988	pasteurized milk	4 °C	2 logs in 7 days	0.407
Farber <i>et al.</i> , 1990	unpasteurized fluid milk	4 °C 10 °C 15 °C	GT in 25.3 hours GT in 10.8 hours GT in 7.4 hours	0.404 0.204 0.142
Rajkowski <i>et al.</i> , 1994	uht milk	12 °C	GT in 4.7 hours	0.337
Rosenow and Marth, 1987	skim, whole, chocolate milk	4 °C 8 °C	3.3 logs in 18 days 4 logs in 8 days	0.261 0.227
Rosso <i>et al.</i> , 1996	Skim, whole, Chocolate milk	4 °C 8 °C	1.3 days (generation time) 0.54 days (generation time)	0.33 0.252
Ice Cream & Frozen Dairy Products				
Berrang <i>et al.</i> , 1988	ice cream	-18 to -25 °C	0 logs in 2 months	0.000
Dean and Zottola, 1996	soft serve	-18 °C	0 logs in 3 months	0.000
Palumbo and Williams, 1991	Ice cream	-18 °C	0 logs in 14 weeks	0.000
Cultured Dairy Products				
Schaack and Marth, 1988	buttermilk	4 °C	decrease, survives 2.5-13 wk	-0.02
	yogurt	4 °C	decrease, survived 4-12 days (~1 log decline detectable)	-0.18
Choi <i>et al.</i> , 1988	yogurt	4 °C	survives 21-24 days, most drop in first 8-12 days (~2 log decline detectable)	-0.12
	buttermilk	4 °C	survives 18-26 days	-0.12
Siragusa and Johnson, 1988b	yogurt		high level survived 9 days [2 logs drop in 3-6 days]	-0.40
Miscellaneous Milk Products				
Rosenow and Marth, 1987	cream	4 °C 8 °C	3.3 logs in 18 days 4 logs in 8 days	0.261 0.227
Farrag <i>et al.</i> , 1990	sweetened condensed milk	7 °C	decrease 1.2 logs in 42 days	-0.016
Olsen <i>et al.</i> , 1988	evaporated milk butter	7 °C 4 to 6 °C 13 °C	4 logs in 14 days 1.9 logs in 49 days 2.7 logs in 42 days	0.163 0.039 0.012

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Frankfurters				
Glass and Doyle, 1989	frankfurters	4.4 °C	2.3 logs in 6 weeks	0.064
McKellar <i>et al.</i> , 1994.	frankfurters	5 °C	3.5 logs in 21 days	0.168
McKellar <i>et al.</i> , 1994.	poultry wieners	5 °C	3.5 logs in 21 days	0.090
Wederquist <i>et al.</i> , 1994	turkey	4 °C	7.0 logs in 55 days	0.181
Bedie <i>et al.</i> , 2001	Pork frankfurters	4 °C	3.8 logs in 35 days	0.154
Dry/Semi-Dry Fermented Sausages				
Glass and Doyle, 1989	Summer sausage	4.4 °C	No change in 12 weeks	0.000
Hugas, 1995	Fermented sausage	12 to 14 °C	1.25 logs decrease in 25 days	-0.02
Farber <i>et al.</i> , 1993	German-style American Italian sausage	4 °C	Approximately 1 log in 4 weeks	-0.036
Nisson, 1998	Norwegian fermented dry sausage	4 °C	1 log in 5.5 months	-0.006
Deli Meats				
Glass and Doyle, 1989	bologna	4.4 °C	1 to 2 logs in 14 days	0.131
Grau and Vanderline, 1992	corned beef	4.8 °C	0.13	0.130
Grau and Vanderline, 1992	vacuum packed ham	5 °C	0.30	0.300
Glass and Doyle, 1989	cooked ham	4.4 °C	2 to 3 logs in 28 days	0.131
Beumer <i>et al.</i> , 1996	cooked ham	7 °C	6 logs in 35 days	0.098
Bredholt <i>et al.</i> , 1999	Vacuum packed Cooked ham	8 °C 8 °C	0.16 logs per day 0.2 logs per day	0.0725 0.091
Nyati, 2000	Cooked chicken Beef sirloin	4.5 4.5	19.5 days (generation time) 21.8 days (generation time)	0.438 0.392
Grant <i>et al.</i> , 1993	roast beef	5 °C 10 °C	5 logs in 15 days 5 logs in 6 days	0.333 0.254

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Deli Meats con't				
Glass and Doyle, 1989	chicken, sliced vacuum packed	4.4 °C	4.15 logs in 14 days	0.364
		4.4 °C	5.90 logs in 14 days	0.517
Siragusa and Johnson, 1988a	chicken, homogenate	4.0 °C	5.2 logs in 20 days	0.370
Siragusa and Johnson, 1988a	chicken fillets, breaded	5.0 °C	0.9 logs in 6 days	0.150
Glass and Doyle, 1989	turkey, sliced	4.4 °C	2.0 logs in 14 days	0.175
		4.4 °C	3.11 logs in 28 days	0.136
		4.4 °C	3.08 logs in 14 days	0.270
Glass and Doyle, 1989	turkey, sliced vacuum packed	4.4 °C	3.83 logs in 14 days	0.336
		4.4 °C	5.09 logs in 14 days	0.446
Ingham and Tautorius, 1991	turkey loaf, cooked, uncured, vacuum	3 °C	0.09 logs in 12 days	0.016
Hudson and Mott, 1993a	cooked beef	5 °C	11.9 hour GT	0.607 (aerobic)
		5 °C	8.7 hour GT	0.83 (vacuum- packed)
Pâté and Meat Spreads				
Farber <i>et al.</i> , 1995	pâté	5 °C	0.361 log in 1 day	0.361
Hudson and Mott, 1993a	pâté	4 °C	4 logs in 680 hours	0.143
COMBINATION FOODS				
Deli-type Salads				
Eblen, 2002a [Growth permitting]	Crab salad, store prepared	5 °C	1 log in 10 days	0.100
	Shrimp salad, store prepared	5 °C	2 logs in 14 days	0.143
[No growth permitting]	Shrimp salad, plant prepared	5 °C	No change	0.000
	Chicken salad Store prepared Plant prepared		No change 3 log decrease in 18 days	0.000 -0.167
	Potato salad Store prepared Plant prepared	5 °C	2 log decrease in 13 days 3 log decrease in 10 days	-0.154 -0.333
	Cole slaw Store prepared Plant prepared	5 °C	3 log decrease in 13days 3 log decrease in 6 days	-0.231 -0.500
	Egg salad Store prepared	5 °C	No change	0.000

Food Category Reference	Food	Literature Values		EGR ^c at 5 °C (log ₁₀ cfu/day)
		Temperature	Growth Rate ^{a,b}	
Deli-type Salads con't				
Eblen, 2002a [No growth permitting]	Tuna salad Store prepared	5 °C	No change	0.000
	Ham salad Store prepared	5 °C	3 log decrease in 13 days	-0.231
	Imitation crab salad, store prepared	5 °C	3 log decrease in 19 days	-0.158
Johnson, 1993	Chicken salad High pH Low pH	4 °C	1 log decrease in 20 days	-0.050
			1 log decrease in 7 days	-0.143
	Potato salad High pH Low pH		1 log decrease in 20 days	-0.050
			1 log decrease in 4 days	-0.250
	Pasta salad High pH Low pH		1 log decrease in 9 days	-0.111
			1 log decrease in 6days	-0.250
	Seafood salad High pH Low pH	1 log decrease in 23 days	-0.043	
		1 log decrease in 23 days	-0.043	