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 *et al*., 1999	cold-smoked salmon	4 °C 8 °C 4 °C 8 °C	2.1 logs in 28 days 5.4 logs in 21 days 2.0 logs in 21 days 4.6 logs in 14 days	0.107 0.116 0.136 0.149
Jemmi and Keusch, 1992	hot-smoked trout	4 °C 8 to 10 °C	0.5 logs in 20 days 6.5 logs in 20 days	0.035 0.120
Hudson and Mott, 1993b	cold-smoked salmon	5 °C 10 °C	4 logs in 650 hours 4 to 4.5 logs in 125 hours	0.148 0.249
Szabo and Cahill, 1999	smoked salmon	4 °C 10 °C	3.9 logs in 28 days 2.7 to 4.3 logs in 9 days	0.198 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 10 °C	1.0 to 1.5 logs in 10 days 3 to 3.5 logs in 10 days	0.177 0.099
Pelroy *et al*., 1994b	cold-smoked salmon	5 °C 5 °C 10 °C 10 °C	2.5 to 5 logs in 40 days 2 logs in 40 days 4.5 to 7 logs in 10 days 5 logs in 11 days	0.092 0.050 0.249 0.139
Pelroy *et al*., 1994a	cold-smoked salmon	5 °C 10 °C	4 logs in 50 days 4.5 logs in 15 days	0.080 0.092
Peterson *et al*., 1993	cold-smoked salmon	5 °C 5 °C 10 °C 10 °C 10 °C	3 logs in 20 days 2.5 logs in 20 days 4 logs in 7 days 3.7 logs in 7 days 6 logs in 20 days	0.150 0.125 0.175 0.162 0.092
Rosso *et al*., 1996	smoked salmon	4 °C 8 °C	1 log in 10 days 3 logs in 14 days	0.142 0.097
Nilsson *et al*., 1997	cold-smoked salmon	5 °C	5 logs in 9 days	0.556
Raw Seafood				
Fernandes *et al*., 1998	fresh trout catfish	4 °C 4 °C	1 logs in 15 days 2 logs in 15 days	0.100 0.185
Lovett *et al*., 1990	raw shrimp, crab, surimi and whitefish	7 °C	GT in 12 hours	0.342
Kaysner *et al*., 1990	raw oysters	4 °C	No growth in 21 days	0.000
Leung *et al*., 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]	—

[a]logs = Log_{10} cfu/g
[b]GT = Generation Time
[c]EGR = Exponential Growth Rate

Food Category Reference	Food	Literature Values		EGR[c] at 5 °C (log_{10} cfu/day)
		Temperature	Growth Rate [a,b]	
Raw Seafood (Cont'd)				
Harrison *et al*., 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 *et al*., 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 *et al*., 1988	lettuce, whole, ready to serve	5 °C 12 °C	0.00 to 0.3 logs in 7 days 0.00 to 2.03 logs in 7 days	0.043 0.004
	lettuce, whole, ready to serve, sealed	25 °C	0.00 to 0.31 logs in 7 days	0.002
	lettuce, whole, ready to serve, open	25 °C	0.00 to 0.35 logs in 7 days	0.002
Beuchat and Brackett, 1990b	lettuce, shredded lettuce, shredded lettuce, whole	5 °C 10 °C 10 °C	0.00 to 0.1 logs in 15 days 1.5-2.0 logs in 3 days 1.0 logs in 15 days	0.007 0.204 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 *et al*., 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 21 °C	no growth (death in chopped tomatoes) Growth	0.00 —

[a]Logs = Log_{10} cfu/g
[b]GT = Generation Time
[c]EGR = 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 *et al*., 2000	Asparagus	4 °C 8 °C	0.0087 log decrease per hour 0.038 logs per hour	-0.09 0.413
Beuchat and Brackett, 1990a	carrots, whole and shredded	5 °C 15 °C	no growth up to 7 days no growth up to 7 days	0.00 0.00
Beuchat *et al*., 1986	cabbage, raw, shreds	5 °C	4 logs in 10 days	0.400
Berrang *et al*., 1989	Broccoli	4 °C 15 °C	0.25 to 0.5 logs in 14 to 21 days 3.0 logs in 4 days	0.059 0.109
Berrang *et al*., 1989	Cauliflower	4 °C 15 °C	≤ 0.25 logs in 14 to 21 days 3.0 logs in 4 days	0.020 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 *et al*., 2000	Apple slices (fresh cut)	5 °C 10 °C	0 logs in 6 days 2 logs in 6 days	0 0.102 (air)
Conway *et al*., 2000	Apple slices (fresh cut)	5 °C 10 °C	0 logs in 4 days 2.8 logs in 10 days	0 0.086 (0.5% O, 15% CO_2)
DAIRY PRODUCTS				
Fresh Soft Cheese				
Glass *et al*., 1995	Queso blanco	4 °C	1.4 logs in 14 days	0.142
Mendoza-Yepes *et al*., 1999	Queso fresco	3 °C 7 °C	0.13 log in 1 day 0.5 log in 1 day	0.284 0.285
Genigeorgis *et al*., 1991	Queso fresco, Queso Ranchero Queso Panella	4 °C	-2.0 logs in 30 days -0.8 logs in 10 days 0.3 logs in 30 days 0.3 logs in 18 days 2.127 logs in 10 days 0.21 logs in 30 days 0.44 logs in 36 days	-0.067 -0.080 0.010 0.017 0.212 0.007 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 *et al*., 1991	cottage cheese (multiple brands)	8 °C	0.59 logs in 18 days	0.015
			1.87 decrease in 36 days	-0.024
			0.42 logs in 24 days	0.007
			1.13 logs in 8 days	0.064
			1.87 decrease in 8 days	-0.106
		4 °C	0.39 logs in 24 days	0.023
			0.34 logs in 24 days	0.020
			0.41 logs in 16 days	0.036
			0.94 logs in 36 days	0.037
			1.87 logs decrease in 8 days	-0.333
	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
			1.88 logs in 8 days	0.106
		4 °C	1.53 logs in 30 days	0.072
			3.58 logs in 36 days	0.141
			1.97 logs in 22 days	0.127
	cream cheese	8 °C	2.0 logs decrease in 30 days	-0.030
		4 °C	2.0 logs decrease in 36 days	-0.079
			>2.0 logs decrease in 36 days	-0.056
Cottin *et al*., 1990	cream cheese	4 °C	2 logs in 2 days	1.423
Papageorgiou *et al*., 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 *et al*., 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 *et al*., 1995	mozzarella	5 °C	4 logs in 21 days	0.190
Genigeorgis *et al*., 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 *et al*., 1987	Camembert	4 °C	2 to 3 longs decrease in 365 days	-0.007
Back *et al*., 1993	Camembert	3°C 6°C 10C	0.9 logs in 10 days 1.5 logs in 15 days 2.4 logs in 15 days	0.197 0.074 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 7 °C 4 °C	4.5 logs in 34 days — —	0.022 — — [Not used in risk assessment]
Genigeorgis *et al*., 1991	Blue	4 °C	>2.0 logs decrease in 36 days	-0.056
Genigeorgis *et al*., 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 *et al*., 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 *et al*., 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 *et al*., 1991	Monterey Jack	4 °C	>2.1 logs decrease in 30 days > 2.1 logs decrease in 30 days	-0.070 -0.070
Genigeorgis *et al*., 1991	Limburger	4 °C	2.26 logs decrease in 36 days	-0.064
Genigeorgis *et al*., 1991	Provolone	4 °C	2.36 logs decrease in 36 days	-0.066
Genigeorgis *et al*., 1991	String cheese	4 °C	2.29 logs decrease in 36 days	-0.064
Genigeorgis *et al*., 1991	Muenster	4 °C	2.0 logs decrease in 36 days	-0.056
Hard Cheese				
Whitley *et al*., 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 *et al*., 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 *et al*., 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 *et al*., 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 *et al*., 1991	American process cheese	4 °C	0.18 logs decrease in 36 days 1.84 logs decrease in 36 days	-0.005
	American process cheese with sorbate and citrate	4 °C		-0.051
	Piedmont process cheese	4 °C	1.62 logs decrease in 36 days	-0.045
Glass et al., 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	3°C	1.0 logs decrease in 60 days	-0.017
	Acidified or preservatives			

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 *et al*, 1988	unpasteurized milk	5 °C 7 °C	GT 3.5 in days GT 1.0 in days	0.085 0.173
Northolt *et al*, 1988	pasteurized milk	4 °C	2 logs in 7 days	0.407
Farber *et al*., 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 *et al*., 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 *et al*., 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 *et al*., 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 *et al*., 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	3.3 logs in 18 days	0.261
		8 °C	4 logs in 8 days	0.227
Farrag *et al*., 1990	sweetened condensed milk	7 °C	decrease 1.2 logs in 42 days	-0.016
	evaporated milk	7 °C	4 logs in 14 days	0.163
Olsen *et al*., 1988	butter	4 to 6 °C 13 °C	1.9 logs in 49 days 2.7 logs in 42 days	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 *et al*., 1994.	frankfurters	5 °C	3.5 logs in 21 days	0.168
McKellar *et al*., 1994.	poultry wieners	5 °C	3.5 logs in 21 days	0.090
Wederquist *et al*., 1994	turkey	4 °C	7.0 logs in 55 days	0.181
Bedie et al., 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 *et al*., 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 *et al*., 1996	cooked ham	7 °C	6 logs in 35 days	0.098
Bredholt *et al*., 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 *et al*., 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 4.4 °C	4.15 logs in 14 days 5.90 logs in 14 days	0.364 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 4.4 °C 4.4 °C	2.0 logs in 14 days 3.11 logs in 28 days 3.08 logs in 14 days	0.175 0.136 0.270
Glass and Doyle, 1989	turkey, sliced vacuum packed	4.4 °C 4.4 °C	3.83 logs in 14 days 5.09 logs in 14 days	0.336 0.446
Ingham and Tautorus, 1991	turkey loaf, cooked, uncured, vacuum	3 °C	0.09 logs in 12 days	0.016
Hudson and Mott, 1993a	cooked beef	5 °C 5 °C	11.9 hour GT 8.7 hour GT	0.607 (aerobic) 0.83 (vacuum- packed)
Pâté and Meat Spreads				
Farber *et al*., 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	4 °C		
	High pH		1 log decrease in 20 days	-0.050
	Low pH		1 log decrease in 7 days	-0.143
	Potato salad			
	High pH		1 log decrease in 20 days	-0.050
	Low pH		1 log decrease in 4 days	-0.250
	Pasta salad			
	High pH		1 log decrease in 9 days	-0.111
	Low pH		1 log decrease in 6days	-0.250
	Seafood salad			
	High pH		1 log decrease in 23 days	-0.043
	Low pH		1 log decrease in 23 days	-0.043