Annex to: EFSA's BIOHAZ Panel Scientific opinion "Public health aspects of *Vibrio* spp. related to the consumption of seafood in the EU". doi:10.2903/j.efsa.2024.8896

Annex F – Effect of temperature on *Vibrio* spp. in seafood

Table F.1: Models describing the effect of storage temperatures of seafood between 0 and 40°C on growth and inactivation of *Vibrio parahaemolyticus* and *Vibrio vulnificus*

***Vibrio* spp.**	**Seafood category**	**Seafood type**	**Detail**	**Analytical method**	**T (°C)**	**Growth / inactivation rates (units)**		**Reference**
						Primary model	**Secondary model**	
Vp	Bivalve	Blacklip Rock Oysters (*Saccostrea glomerata*)	Shellstock. Injection in live oysters. Pool of 4 strains isolated from oysters	Direct plating on chromogenic agar	 4 13 18 25	Linear model; inactivation rate /h (log_{10} CFU) -0.0013 ± 0.0007 0.0029 ± 0.0009 Modified Gompertz model; specific growth rate, μ /h (log_{10} CFU) 0.032 ± 0.011 0.047 ± 0.021		Padovan et al. (2023)
Vp	Bivalve	Oysters (*Crassostrea gigas*)	Shellstock. Injection in live oysters. Pool of three ST36 strains	MPN-PCR	 15 20 25 30	Linear model; specific growth rate, μ /h (log_{10} MPN) 0.091 0.062 0.188 0.263		Ellett et al. (2022)
Vp	Bivalve	Oysters (*C. gigas*)	Shellstock. Injection in live oysters. Pool of four non-ST36 strains	MPN-PCR	 15 20 25 30	Linear model; specific growth rate, μ /h (log_{10} MPN) 0.043 0.057 0.300 0.352		Ellett et al. (2022)
Vp	Bivalve	Oysters (*C. gigas*)	Shellstock. Natural occurrence.	MPN-PCR	 15 20	Linear model; specific growth rate, μ /h (log_{10} MPN) 0.050 0.080		Ellett et al. (2022)

					25	0.120		
Vp	Bivalve	Oysters (Crassostrea spp.)	Inoculation of sterilised oyster samples with ATCC 17802	Direct plating on TCBS	 37	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 2.15		Wang et al. (2018)
Vp	Bivalve	Oysters (Crassostrea spp.)	Inoculation of sterilised oyster samples with ATCC 33847	Direct plating on TCBS	 37	Modified Gompertz; maximum specific growth rate, μ_{max} /h (log CFU) 1.51		Wang et al. (2018)
Vp	Bivalve	Oysters (*C. gigas*)	Shellstock. Injection. Pool of six strains.	Direct plating on TCBS	 3.6 6.2 9.6 12.6 18.4 20.0 25.7 30.4	Linear model; inactivation rate /h (log_{10} CFU) -0.006 -0.004 -0.005 -0.003 Baranyi model; specific growth rate, μ /h (log_{10} CFU) 0.030 0.075 0.095 0.282	Arrhenius model $Ln\ \mu = \ln 1.81\times10^{-9} + 4131.2\times[1/(T+273.15)]$ Square root model $SQRT(\mu) = 0.0303 \times (T-13.37)$	Fernandez-Piquer et al. (2011)[a]
Vp	Bivalve	Oysters (*Crassostrea virginica*)	Shellstock. Natural occurrence. Two sets of observations (2 years).	Colony hybridization	 5 10 15 20 25 30	Baranyi model; inactivation rate /h (log CFU) -0.0036 / -0.0012 -0.0009 / -0.0019 Baranyi model; specific growth rate, μ /h (log CFU) 0.054 / 0.022 0.107 / 0.058 0.280 / 0.177 0.264 / 0.175	 Square root model $SQRT(\mu) = 0.0203\times(T-5.105)$	Parveen et al. (2013)
Vp	Bivalve	Oysters (C. virginica)	Shellstock. Inoculum with pool of five strains.	rt RT-PCR (RNA)	 0 4 10	Baranyi model; minimum value of inactivation rate, μ_{min} /day (log_{10} CFU) -0.134 -0.0886 -0.073	Arrhenius model $Ln\ \mu = \ln 7.503\times10^{-9} + 4543.456/(T+273.15)$	Liao et al. (2017)
Vp	Bivalve	Oysters (*C. virginica*)	Shellstock. Inoculum with pool of five strains.	Direct plating on TCBS	 0 4 10	Baranyi model, minimum value of inactivation rate, μ_{min} /day (log_{10} CFU) -0.245 -0.152 -0.121	Arrhenius model $Ln\ \mu = \ln 9.156\times10^{-10} + 5280.115/(T+273.15)$	Liao et al. (2017)

Vp	Bivalve	Oysters (*C. gigas*)	Slurry from frozen oysters. Non-pathogenic strain.	Direct plating on TCBS	 10 15 20 25 30	Modified Gompertz; specific growth rate, μ /h (log CFU) 0.063 NR NR NR NR	Square root model SQRT(μ) = 0.084735×(T-17.79)	Yoon et al. (2008)
Vp	Bivalve	Oysters (*C. gigas*)	Slurry from frozen oysters. TRH+ strain.	Direct plating on TCBS	 10 15 20 25 30	Modified Gompertz; specific growth rate, μ /h (log CFU) 0.032 NR NR NR NR	Square root model SQRT(μ) = 0.085029×(T-20.31)	Yoon et al. (2008)
Vp	Bivalve	Oysters (*C. gigas*)	Shellstock. Natural occurrence. Three sets of observations (3 years)	MPN-PCR	 5 10 15 20 25 30	Log-Linear model; inactivation rate /h (log_{10} MPN) -0.00863 / -0.00118 / -0.00060 Log-Linear model; specific growth rate, μ /h (log_{10} MPN) 0.00158 / -0.00126 / 0.00088 0.00419 / 0.00110 / 0.00150 0.01477 / 0.01066 / 0.01135 0.02228 / 0.01975 / 0.01851 0.04636 / 0.04671 / 0.04521	 Square root model SQRT(μ) = 0.0096 × (T-8.44)	Fletcher et al. (2024)
Vp	Crustacean	Shrimps (Litopenaeus vannamei)	Natural occurrence.	PMA-qPCR	 4 7 15 20 25 30	Baranyi model; inactivation rate /h (log CFU) -0.019 -0.025 Baranyi model; maximum specific growth rate, μ_{max} /h (log CFU) 0.044 0.105 0.179 0.336	 Square root model SQRT(μ_{max}) = 0.026 × (T-7.664)	Wu et al. (2023)
Vp	Crustacean	Shrimp (*L. vannamei*)	Boiled. Inoculum by immersion. O3:K6 TDH+ strain.	Direct plating on TCBS	 12 15 20 25 30 35 37 40	Linear model; maximum specific growth rate, μ_{max} /h (log_{10} CFU) 0.11 0.17 0.46 0.71 0.82 1.33 1.47 1.44	Square root model SQRT(μ_{max}) = 0.03 × (T-1.0)	Tang et al. (2015)

Vp	Crustacean	Shrimp (*L. vannamei*)	Gamma irradiated. Inoculum with pool of two strains.	Direct plating on TCBS	8 10 12 15 20 23 25 30 32 35	No growth No growth Huang model; maximum specific growth rate, μ_{max} /h (ln CFU) NR NR NR NR NR NR NR NR	 Suboptimal Huang square-root $SQRT(\mu_{max}) = 0.144\times(T-10.8)^{0.75}$	Chen et al. (2019)
Vp	Crustacean	Shrimp (*L. vannamei*)	Inoculation of sterilised shrimp samples with ATCC 17802.	Direct plating on TCBS	 37	Modified Gompertz; maximum specific growth rate, μ_{max} /h (log CFU) 2.82		Wang et al. (2018)
Vp	Crustacean	Shrimp (*L. vannamei*)	Inoculation of sterilised shrimp samples with ATCC 33847.	Direct plating on TCBS	 37	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 2.04		Wang et al. (2018)
Vp	Crustacean	Prawn (*L. vannamei*)	Frozen, ready-to-cook product. Inoculum by immersion. TDH+ strain.	MPN-PCR	 0 4 10 15 20 25 37 44	Modified Gompertz model; inactivation rate /h (ln MPN) NR NR NR Baranyi model; maximum specific growth rate, μ_{max} /h (ln MPN) NR NR NR NR NR	Kohler model Maximum growth/death rate = $0.0066^2(T-(-40.2))^2(1-\exp((4.1133)(T-10.1)))^2$ Modified Ratkowsky model Maximum growth/death rate = $6.5528(T-10.1)^2(1-\exp((0.0001)(T-47.1)))^2$	Boonyawantang et al. (2012)
Vp	Crustacean	Crab	Soy sauce marinated (“*ganjang-gejang*”). Inoculum with pool of	Spiral plating on TCBS	 5 10 15	Baranyi model; specific growth rate, μ_{max} /h (log CFU) < 0.00 < 0.00 Baranyi model; specific growth rate, μ_{max} /h (log CFU) 0.14	 Four-parameter polynomial μ_{max}= -6.5 + (0.8687×T) +	Chung et al. (2019)

			three strains.		20 25 30	0.50 0.55 0.66	($-0.0358\times T^2$) + ($0.000493\times T^3$)	
Vp	Crustacean	Shrimp	Boiled. Inoculum by immersion with a pool of four strains.	Direct plating on TCBS	 4 7 15 20 25 30	Log-linear model; maximum specific inactivation rate; $K_{max\ B}$ /min (log_{10} CFU) 4.73 4.42 Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log_{10} CFU) 0.23 0.85 1.10 1.16	 Non-linear Arrhenius model. Parameter estimates not provided.	Ma et al. (2016)
Vp	Finfish	Salmon (Oncorhynchus spp.)	Salmon meat. Inoculum by immersion	Direct plating on TCBS	 0 3 6 9 12 16 20 25 30 35	Weibull model; log_{10} R = -b × t^n with b=0.00063; n=1.6093 b=0.00048; n=1.5913 b=0.00035; n=1.5425 b=0.00028; n=1.5279 b=0.00011; n=1.5122 Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log_{10} CFU) 0.0205 0.1192 0.3330 0.5583 0.9121	Linear regression of Weibull b and n versus T with *b* =-4.2667 × 10^5 × T + 0.0006 *n* = -0.0086 × T + 1.6082 Square root model SQRT(μ_{max}) = 0.0421×(T-12.0570)	Yang et al. (2009)
Vp	Finfish	Tilapia (Tilapia spp.)	Inoculation of sterilised tilapia samples with ATCC 17802	Direct plating on TCBS	 37	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 2.28		Wang et al. (2018)
Vp	Finfish	Tilapia (Tilapia spp.)	Inoculation of sterilised tilapia samples with ATCC 33847	Direct plating on TCBS	 37	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 1.84		Wang et al. (2018)
Vp	Finfish	Salmon (*Salmonidae* spp.)	Sashimi. Inoculum with ATCC 33844.	Direct plating on TCBS	 13 18 24	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 0.059±0.02 0.103±0.12 0.185±0.27	Square root model SQRT(μ_{max}) = 0.01052×(T+13.52)	Kim et al. (2012)

					30 36	0.219±0.76 0.256±0.24		
Vp	Finfish	Flounder (*Paralichthys* spp.)	Sashimi. Inoculum with ATCC 33844.	Direct plating on TCBS	 13 18 24 30 36	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 0.037±0.04 0.105±0.09 0.152±0.21 0.304±0.02 0.435±0.21	Square root model SQRT(μ_{max}) = 0.02017×(T−3.223)	Kim et al. (2012)
Vv	Bivalve	Oysters (*C. gigas*)	Shucked. Natural occurrence.	Direct plating on chromogenic agar	 16 18 24 30 36	Modified Gompertz model; maximum specific growth rate, μ_{max} /h (log CFU) 0.125 0.083 0.138 0.260 0.328	Square root model SQRT(μ_{max}) = 0.01380×(T+5.604)	Kim et al. (2012)
Vv	Bivalve	Oysters (*C. virginica*)	Shellstock. Natural occurrence. Three sets of observations (spring, summer, fall)	MPN-hybridisation	 5 10 15	Baranyi model; specific growth rate, μ /h (log MPN) -0.002 / -0.007 / ND -0.004 / -0.005 / -0.004 0.016 / 0.028 / ND		DaSilva et al. (2012)
					  20 25 30	Baranyi model; specific growth rate, μ /h (log MPN) 0.049 / ND / 0.035 0.091 / 0.098 / 0.073 0.064 / 0.095 / 0.121	Square root model SQRT(μ) = 0.0109×(T-0.7005)	

Abbreviations: CFU, colony forming unit; MPN, most probable number; ND, not determined; NR, not reported; TCBS, Thiosulfate Citrate Bile Sucrose agar; PMA-qPCR, qPCR combined with pretreatment with propidium monoazide; b, scale factor, n, shape factor of Weibull distribution.
Note: the models herein summaried are expressed in the units as reported in the source references. In some instances, there are potential ambiguities on which type of logarithmic transformations are used in the papers, since log can refer to either the natural logarithm or the decimal logarithm. Generally, the use of log, $\log_{10}$ or ln is not always consistent or easy to deduce from reading papers. It is therefore recommended to contact authors to clarify this before using the models since mixing them up will result in a factor of 2.3 difference.
[a]Data in ComBase (https://www.combase.cc/) accessed in April 2024.

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