2.3.17 Food-matrices Exterior Time-temperature Simulations: Gradual Heating 56°C

Table 313. Assessment of individual model fit for strains following gradual heating at 56°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12662 ST-257, CC-257	Gradual Heat (Un-chilled)	0.430	0.817	10.180
12662 ST-257, CC-257	Gradual Heat (Pre-chilled)	0.364	0.906	12.850
13126 (ST-21, CC-21)	Gradual Heat (Un-chilled)	0.515	0.865	9.640
13126 (ST-21, CC-21)	Gradual Heat (Pre-chilled)	0.357	0.807	10.560
13136 (ST-45, CC-45)	Gradual Heat (Un-chilled)	0.326	0.856	10.950
13136 (ST-45, CC-45)	Gradual Heat (Pre-chilled)	0.448	0.759	7.090

Table 314. Mixed Weibull distribution model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following gradual heating at 56°C.

Parameters	Estimates	Standard Error
α	2.355	0.301
δ1	10.184	0.709
p	5.359	2.186
N0	5.730	0.254
δ2	27.180	5.993

Table 315. Weibull model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and gradual heating at 56°C.

Parameters	Estimates	Standard Error
Nres	3.032	0.105
δ	12.839	0.560
p	7.242	2.788
N0	5.678	0.192

Table 316. Mixed Weibull distribution model for survival of strain 13126 (ST-21, CC-21) following exposure to gradual direct heating at 56°C.

Parameters	Estimates	Standard Error
α	1.685	0.248
δ1	9.643	0.515
p	6.000	4.987
N0	4.167	0.172
δ2	22.930	1.692

Table 317. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following exposure to gradual heating at 56^{o}C.

Parameters	**Estimates**	**Standard Error**
Sl	7.376	1.761
Kmax	0.703	0.250
Nres	2.008	0.136
N0	4.129	0.205

Table 318. Mixed Weibull distribution model for survival of strain 13136 (ST-45, CC-45) following exposure to gradual heating at 56^{o}C.

Parameters	**Estimates**	**Standard Error**
α	1.887	0.234
δ1	10.955	0.650
p	4.746	2.018
N0	5.696	0.192
δ2	25.819	3.644

Table 319. Weibull model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following prior chilling and exposure to gradual heating at 56^{o}C.

Parameters	**Estimates**	**Standard Error**
Nres	3.180	0.190
δ	7.091	2.204
p	1.371	0.635
N0	5.977	0.317

2.3.18 Food-matrices Exterior Time-temperature Simulations: Gradual Heating 56°C

Predicted Response Curves:

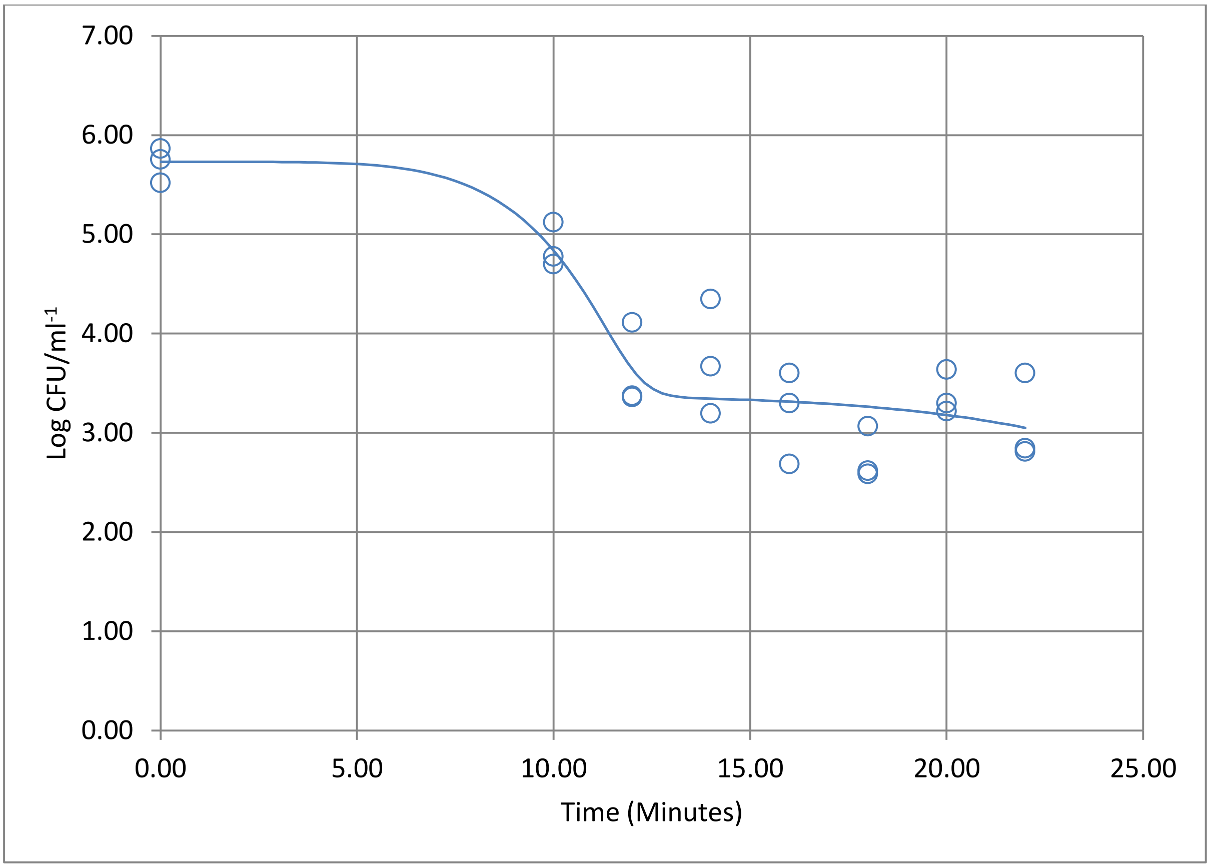

Figure 333. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 12662 (ST-257, CC-257) following gradual heating at 56°C.

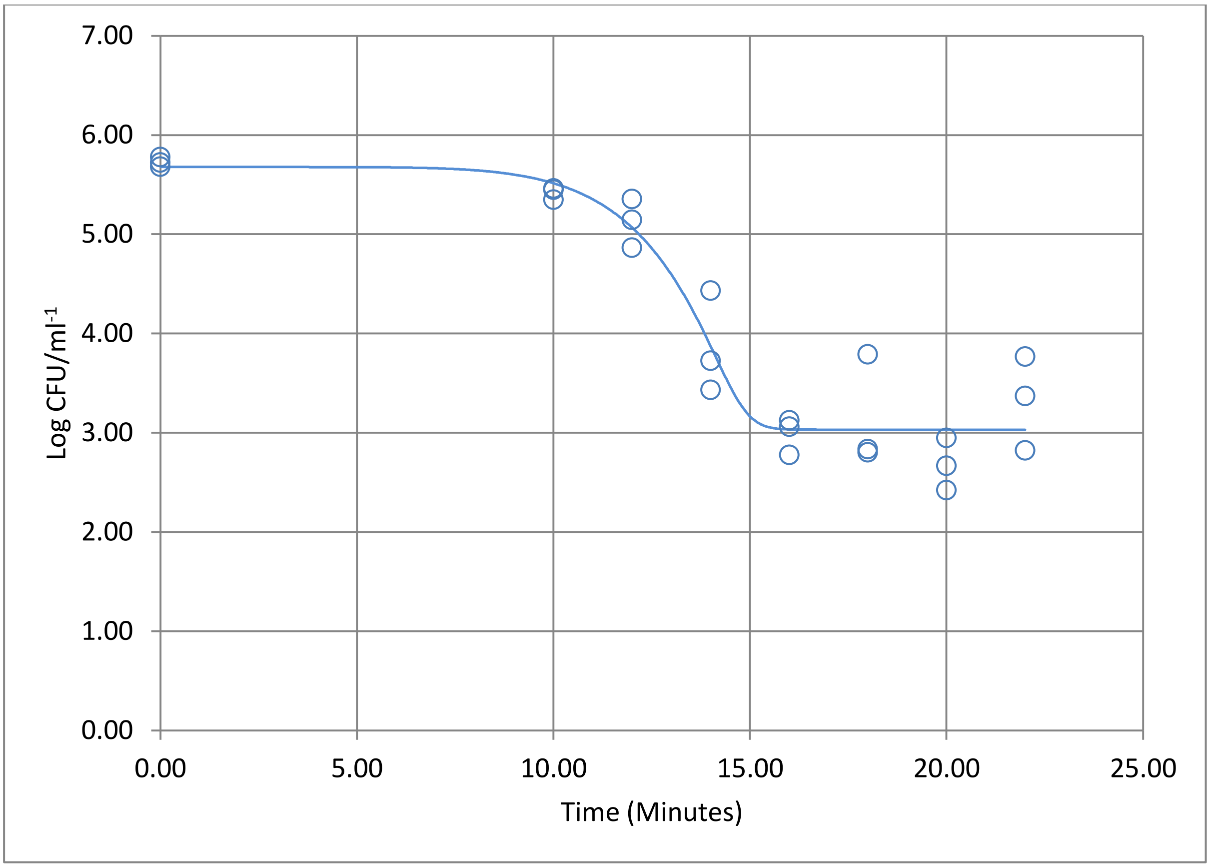

Figure 334. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following prior chilling and gradual heating at 56°C.

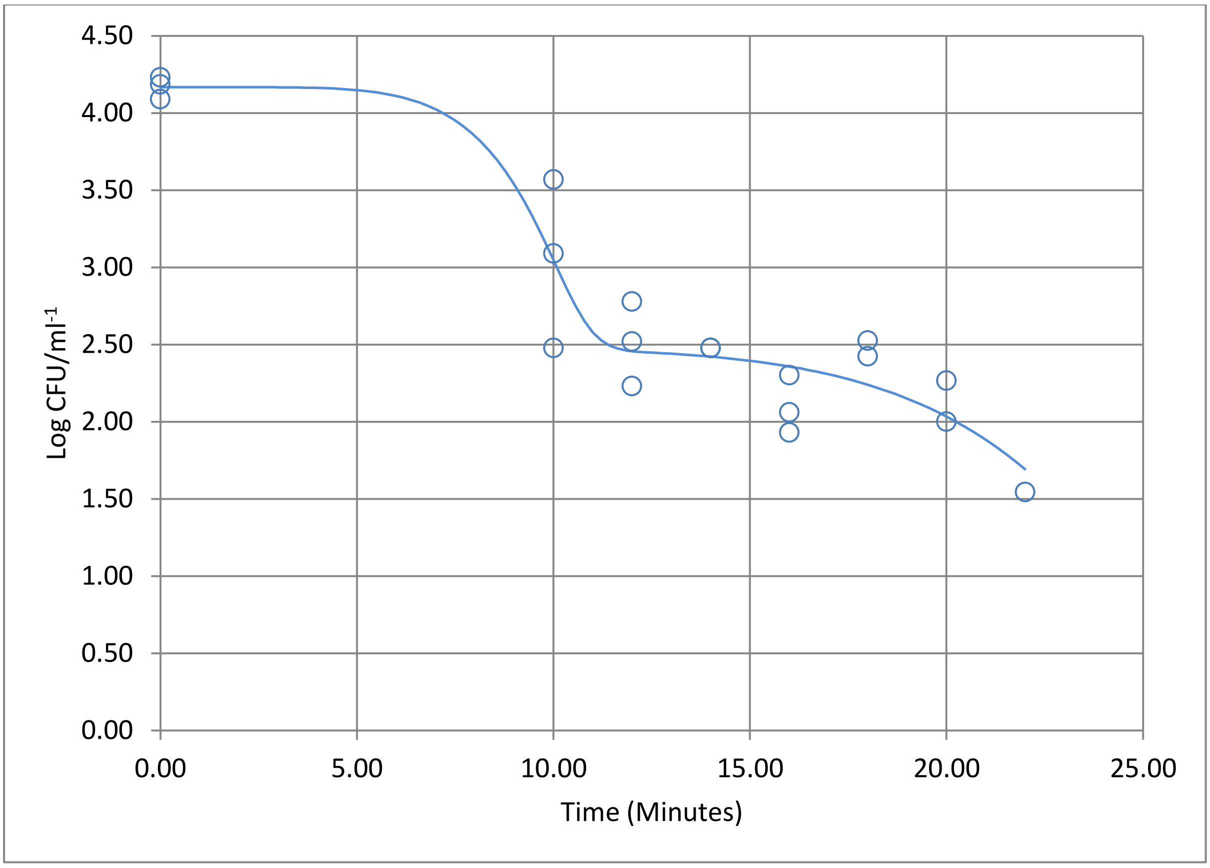

Figure 335. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13126 (ST-21, CC-21) following gradual heating at 56°C.

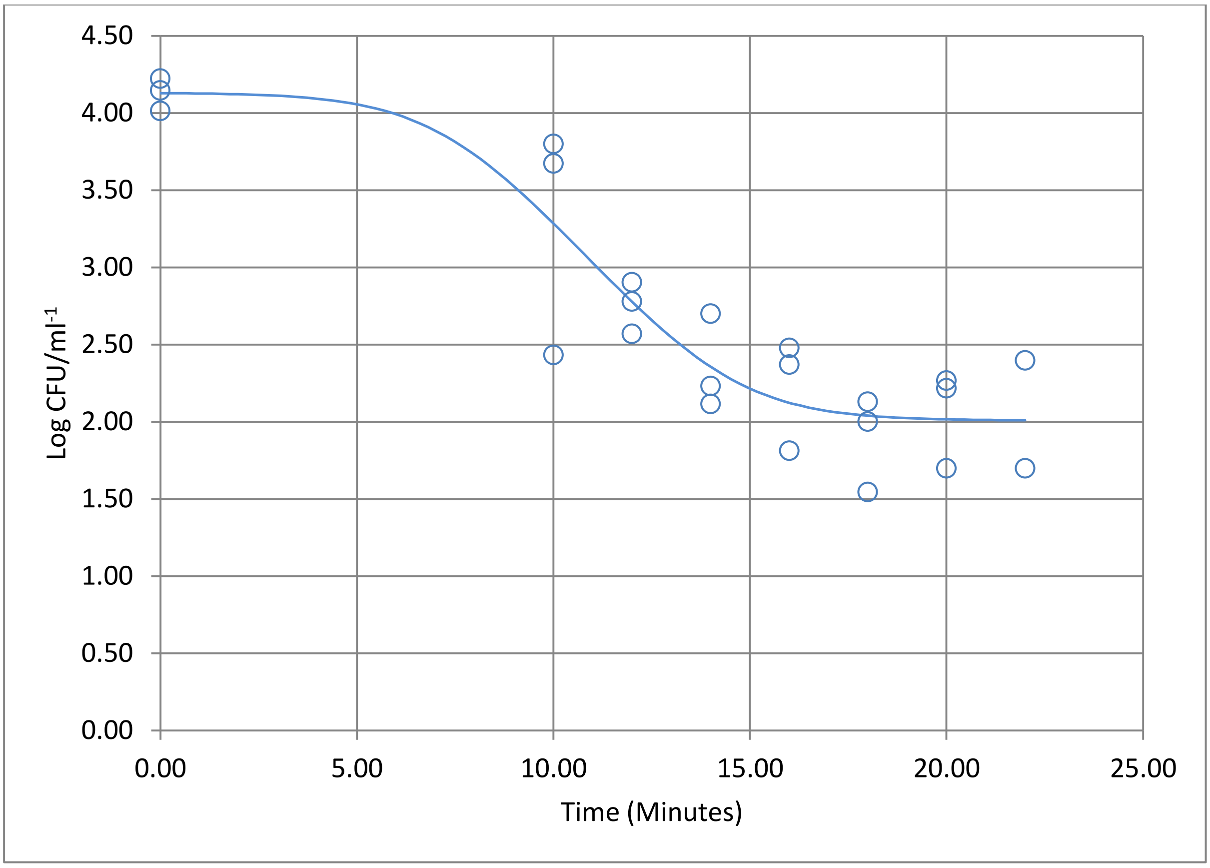

Figure 336. Plot illustrating predicted response curve for Log-linear model incorporating shoulder effect and an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and gradual heating at 56°C.

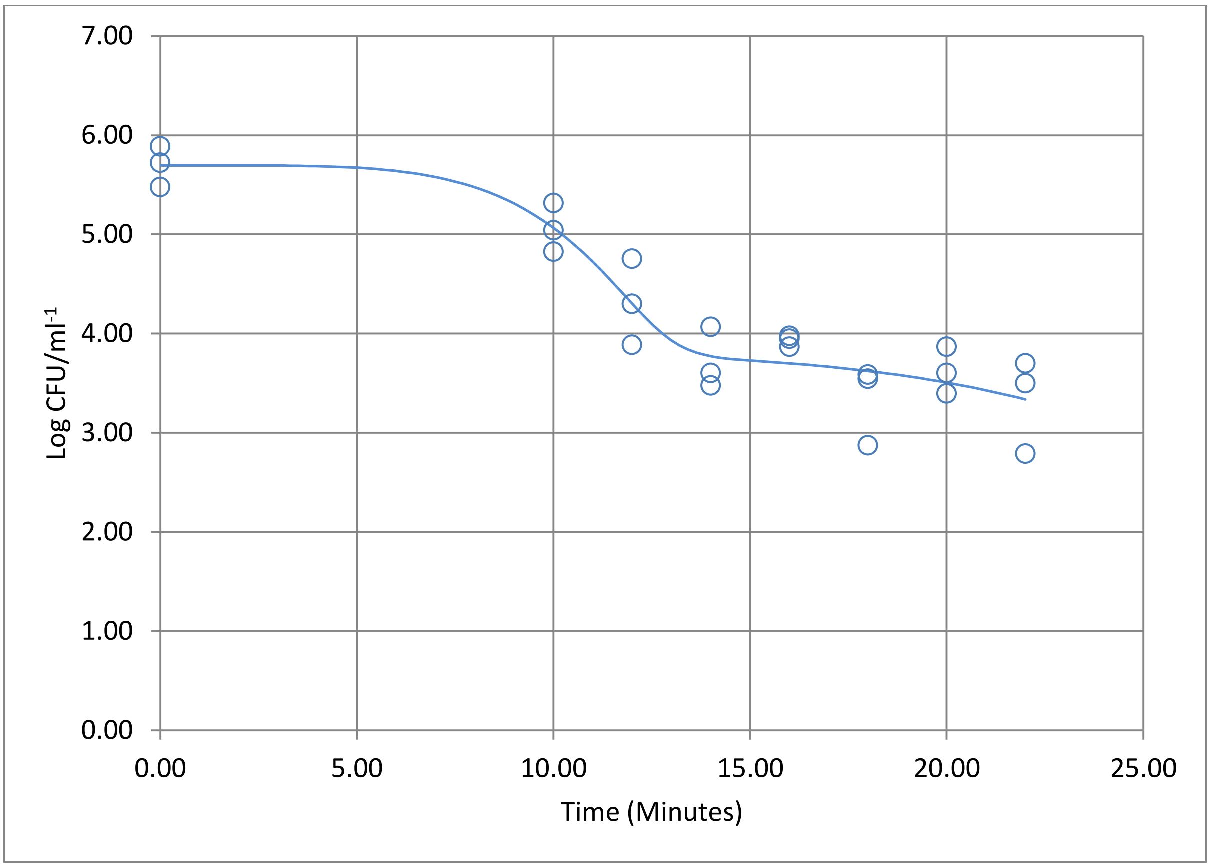

Figure 337. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13136 (ST-45, CC-45) following gradual heating at 56°C.

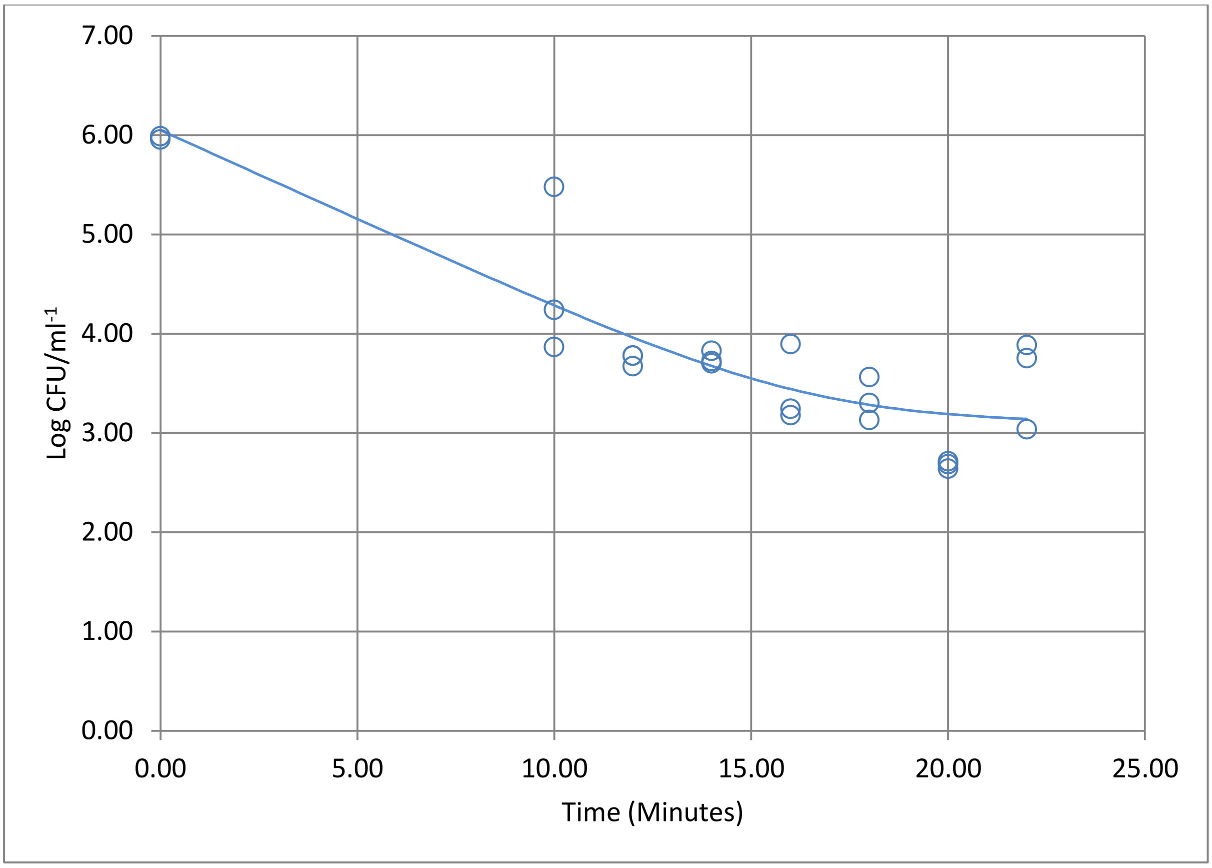

Figure 338. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following prior chilling and gradual heating at 56°C.

2.3.19 Food-matrices Exterior Time-temperature Simulations: Gradual Heating 70^{o}C

Table 320. Assessment of individual model fit for strains following gradual heating at 70^{o}C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	Gradual Heat (Un-chilled)	0.636	0.839	10.860
12628 (ST-1773, CC-828)	Gradual Heat (Pre-chilled)	0.577	0.804	8.961
12662 ST-257, CC-257	Gradual Heat (Un-chilled)	0.495	0.867	9.860
12662 ST-257, CC-257	Gradual Heat (Pre-chilled)	0.624	0.746	3.280
13126 (ST-21, CC-21)	Gradual Heat (Un-chilled)	0.857	0.702	11.290
13126 (ST-21,CC-21)	Gradual Heat (Pre-chilled)			
13136 (ST-45, CC-45)	Gradual Heat (Un-chilled)	0.568	0.852	9.750
13136 (ST-45, CC-45)	Gradual Heat (Pre-chilled)			

Table 321. Mixed Weibull distribution model for survival of strain 12628 (ST-1773, CC-828) following exposure to gradual heating at 70^{o}C.

Parameters	Estimates	Standard Error
α	2.834	0.430
δ1	10.863	0.916
p	6.000	3.533
N0	5.914	0.364
δ2	20.476	1.746

Table 322. Weibull model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following prior chilling and exposure to gradual heating at 70^{o}C.

Parameters	Estimates	Standard Error
Nres	2.731	0.204
δ	8.961	1.065
p	4.388	2.915
N0	5.773	0.333

Table 323. Weibull model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following gradual heating at 70^{o}C.

Parameters	Estimates	Standard Error
Nres	2.263	0.190
δ	9.858	1.112
p	3.117	0.983
N0	5.619	0.284

Table 324. Weibull model for survival of strain 12662 (ST-257, CC-257) following prior chilling and gradual heating at 70°C.

Parameters	**Estimates**	**Standard Error**
δ	3.275	2.058
p	0.675	0.221
N0	5.874	0.360

Table 325. Mixed Weibull distribution model for survival of strain 13126 (ST-21, CC-21) following gradual heating at 70°C.

Parameters	**Estimates**	**Standard Error**
α	3.308	0.849
δ1	11.289	1.734
p	6.000	4.292
N0	5.493	0.776
δ2	25.846	7.678

Table 326. Mixed Weibull distribution model for survival of strain 13136 (ST-45, CC-45) following gradual heating at 70°C.

Parameters	**Estimates**	**Standard Error**
α	3.458	0.432
δ1	9.753	1.106
p	3.864	1.709
N0	5.307	0.333
δ2	36.976	20.204

2.3.20 Food-matrices Exterior Time-temperature Simulations: Gradual Heating 70^{o}C

Predicted Response Curves:

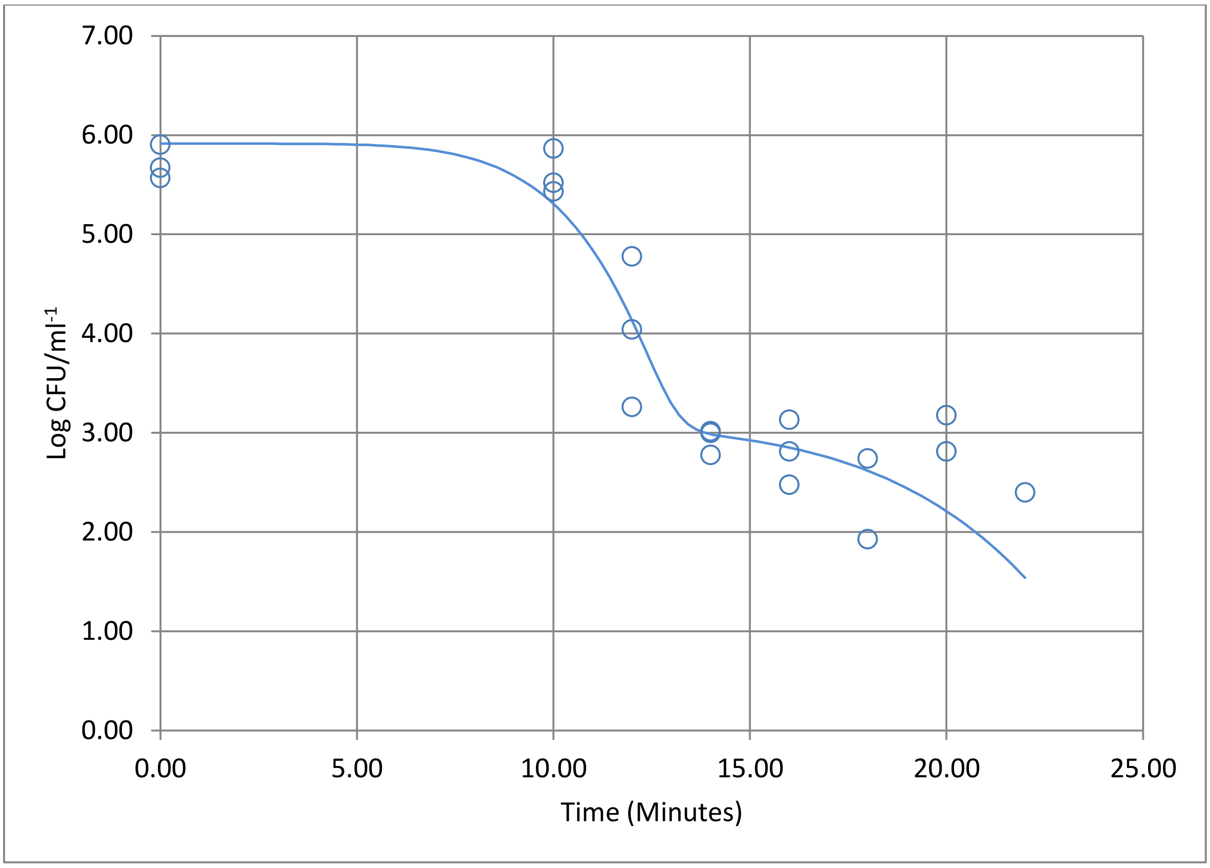

Figure 339. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 12628 (ST-1773, CC-828) following gradual heating at 70°C.

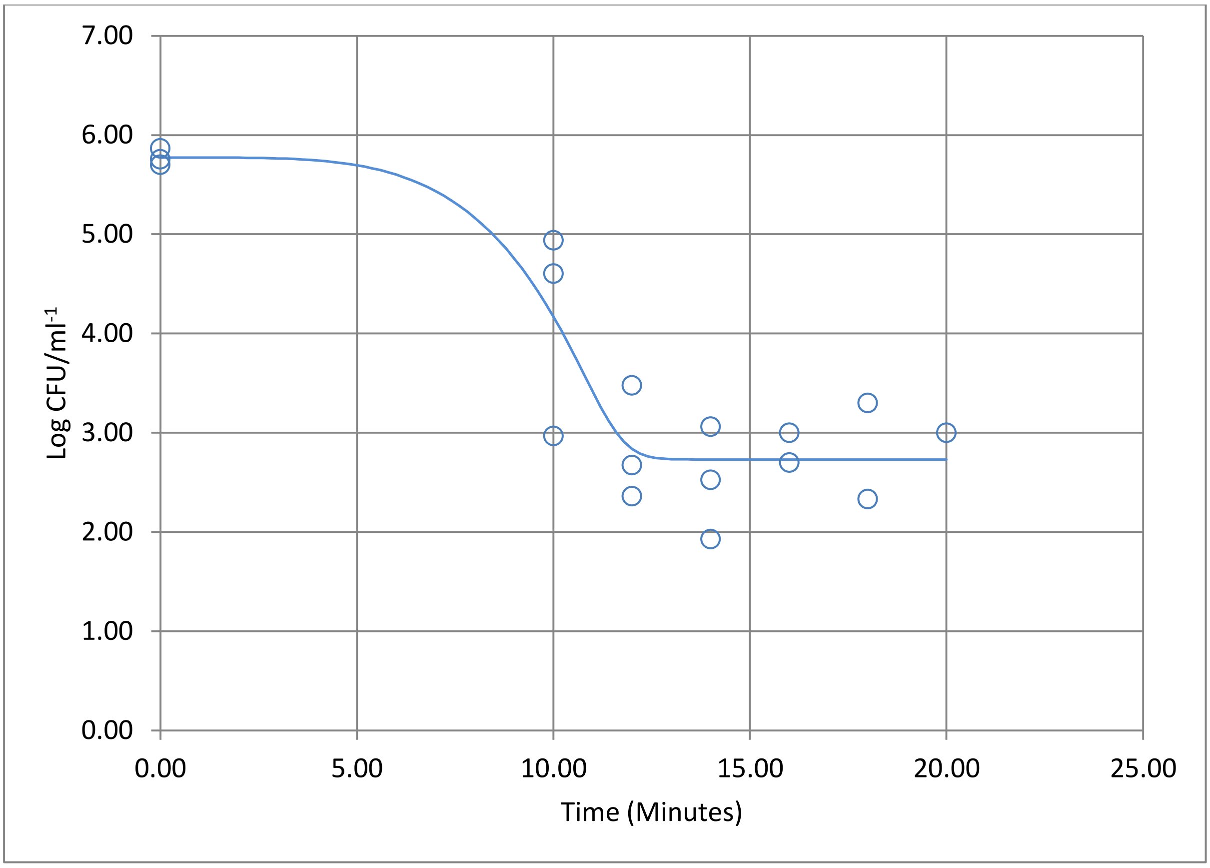

Figure 340. Plot illustrating predicted response curve using a Weibull model with an asymptotic function for strain 12628 (ST-1773, CC-828) following prior chilling and gradual heating at 70°C.

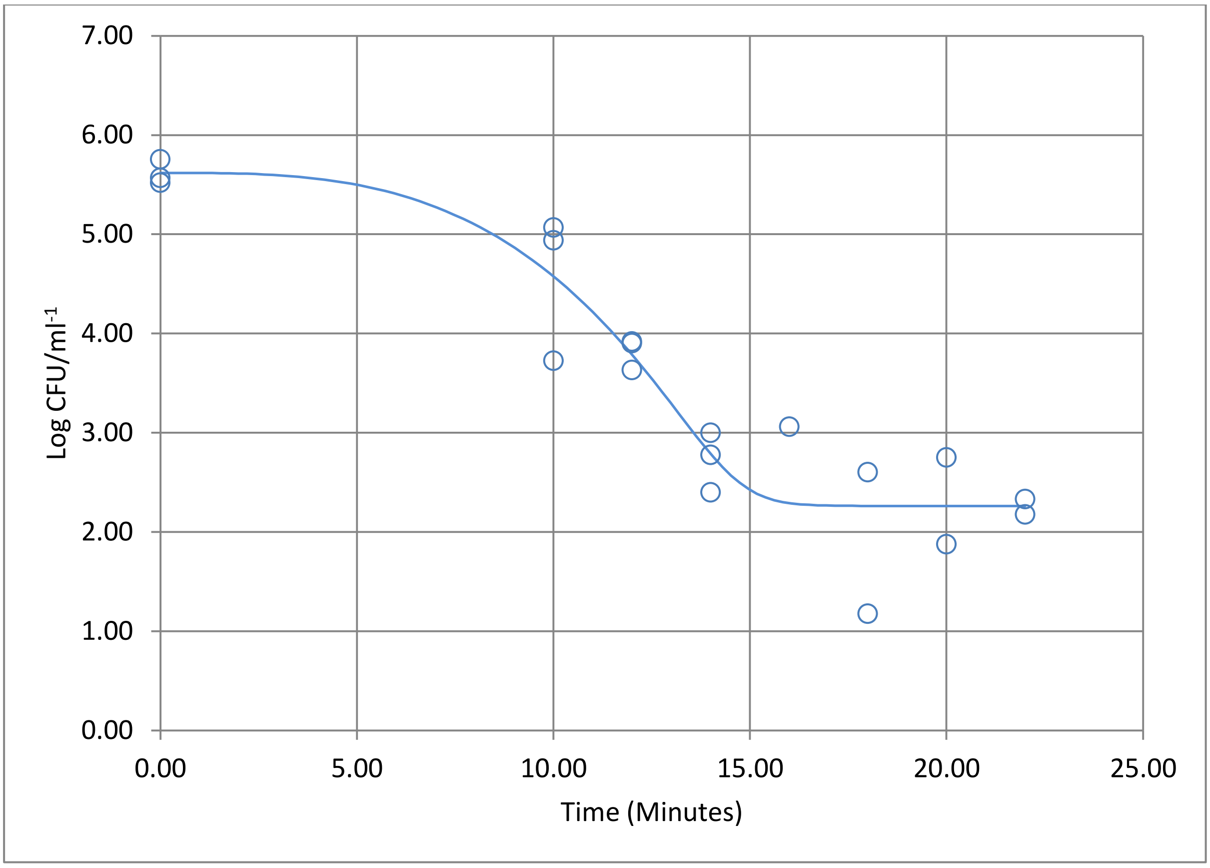

Figure 341. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following gradual heating at 70°C.

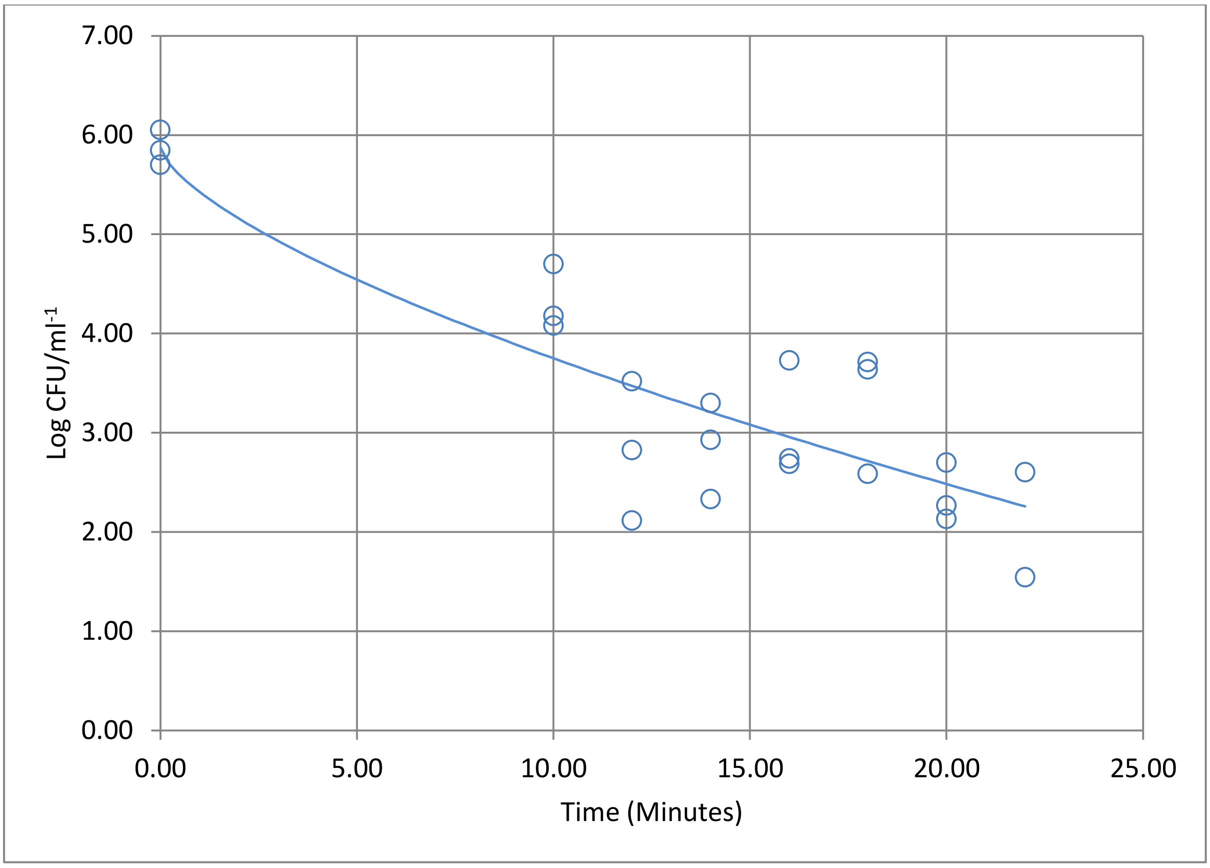

Figure 342. Plot illustrating predicted response curve using a Weibull model for strain 12662 (ST-257, CC-257) following prior chilling and gradual heating at 70°C.

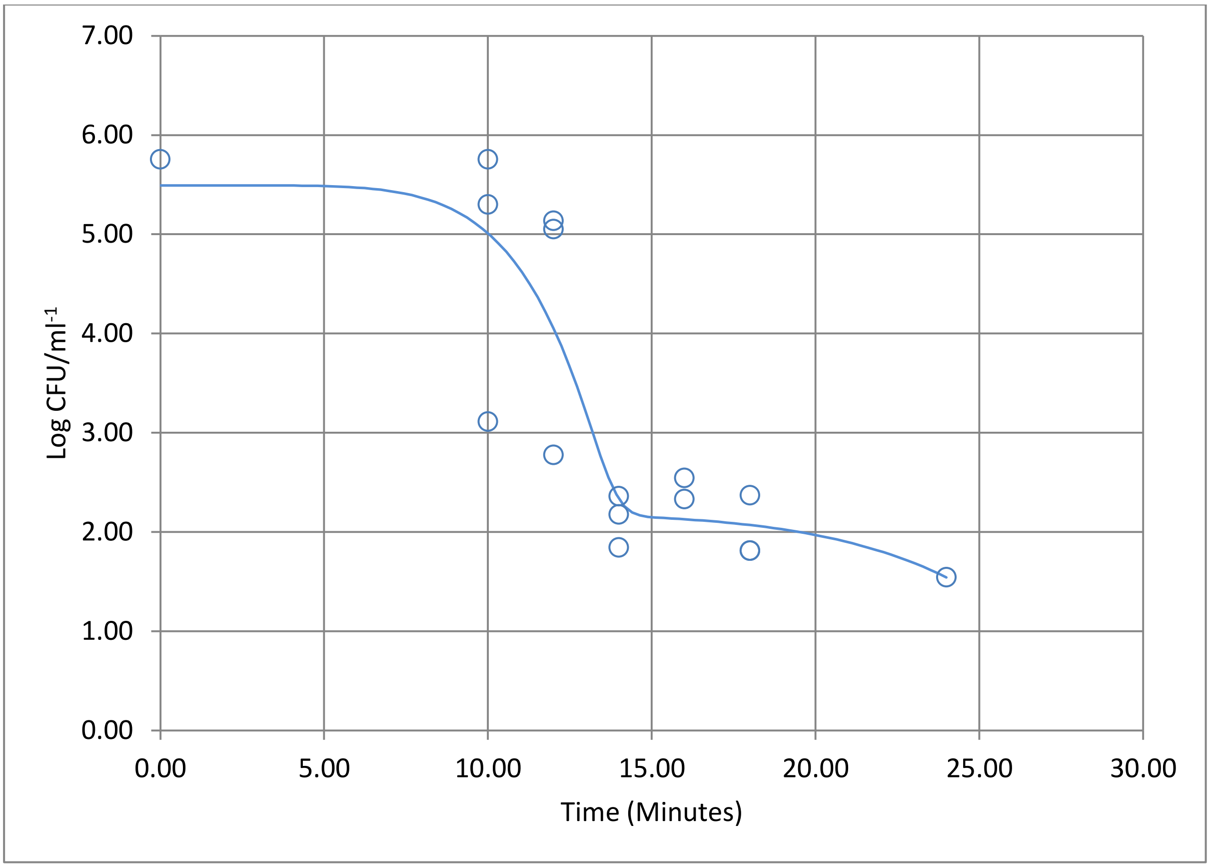

Figure 343. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13126 (ST-21, CC-21) following gradual heating at 70°C.

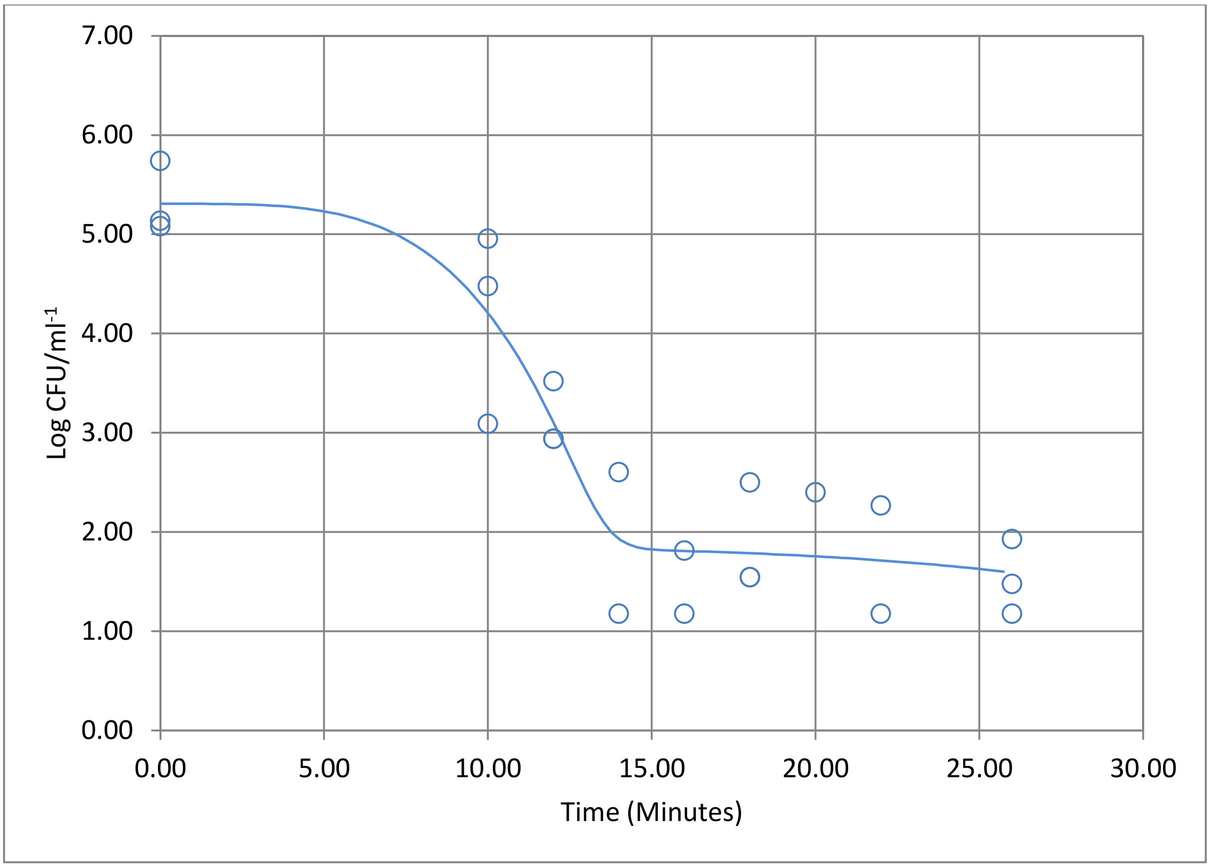

Figure 344. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13136 (ST-45, CC-45) following gradual heating at 70°C.

2.3.21 Food-matrices Exterior Time-temperature Simulations: Direct Heating 56°C

Table 327. Assessment of individual model fit for strains following direct heating at 56°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	Direct Heat (Un-chilled)	0.390	0.587	1.042
12628(ST-1773, CC-828)	Direct Heat (Pre-chilled)	0.407	0.661	1.155
12662 (ST-257, CC-257)	Direct Heat (Un-chilled)	0.390	0.587	1.000
12662 (ST-257, CC-257)	Direct Heat (Pre-chilled)	0.279	0.809	1.690
13126 (ST-21, CC-21)	Direct Heat (Un-chilled)	0.613	0.733	0.006
13126 (ST-21, CC-21)	Direct Heat (Pre-chilled)	0.765	0.666	0.080
13136 (ST-45, CC-45)	Direct Heat (Un-chilled)	0.300	0.809	1.432
13136 (ST-45, CC-45)	Direct Heat (Pre-chilled)	0.469	0.755	1.180

Table 328. Log-linear model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following exposure to direct heating at 56°C.

Parameters	Estimates	Standard Error
Kmax	4.215	1.409
Nres	4.213	0.076
N0	5.694	0.168

Table 329. Biphasic model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following prior chilling and exposure to direct heating at 56°C.

Parameters	Estimates	Standard Error
Kmax	2.209	0.695
Nres	4.206	0.116
N0	5.82	0.227

Table 330. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following exposure to direct heating at 56°C.

Parameters	Estimates	Standard Error
Kmax	2.708	1.013
Nres	3.689	0.105
N0	5.055	0.224

Table 331. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and exposure to direct heating at 56^{o}C.

Parameters	Estimates	Standard Error
Kmax	1.346	0.306
Nres	3.902	0.090
N0	5.503	0.148

Table 332. Weibull model for survival of strain 13126 (ST-21, CC-21) following exposure to direct heating at 56^{o}C.

Parameters	Estimates	Standard Error
δ	0.006	0.021
p	0.155	0.074
N0	5.453	0.354

Table 333. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and exposure to direct heating at 56^{o}C.

Parameters	Estimates	Standard Error
Kmax	6.338	2.558
Nres	2.876	0.198
N0	5.536	0.442

Table 334. Mixed Weibull distribution model for survival of strain 13136 (ST-45, CC-45) following exposure to direct heating at 56^{o}C.

Parameters	Estimates	Standard Error
α	1.333	0.252
δ1	1.432	0.323
p	1.776	0.837
N0	5.220	0.179
δ2	17.268	9.309

Table 335. Mixed Weibull distribution model for survival of strain 13136 (ST-45, CC-45) following prior chilling and exposure to direct heating at 56°C.

Parameters	Estimates	Standard Error
α	1.546	0.434
δ1	1.181	0.445
p	1.279	0.805
N0	5.440	0.279
δ2	10.614	4.636

2.3.22 Food-matrices Exterior Time-temperature Simulations: Direct Heating 56°C

Predicted Response Curves:

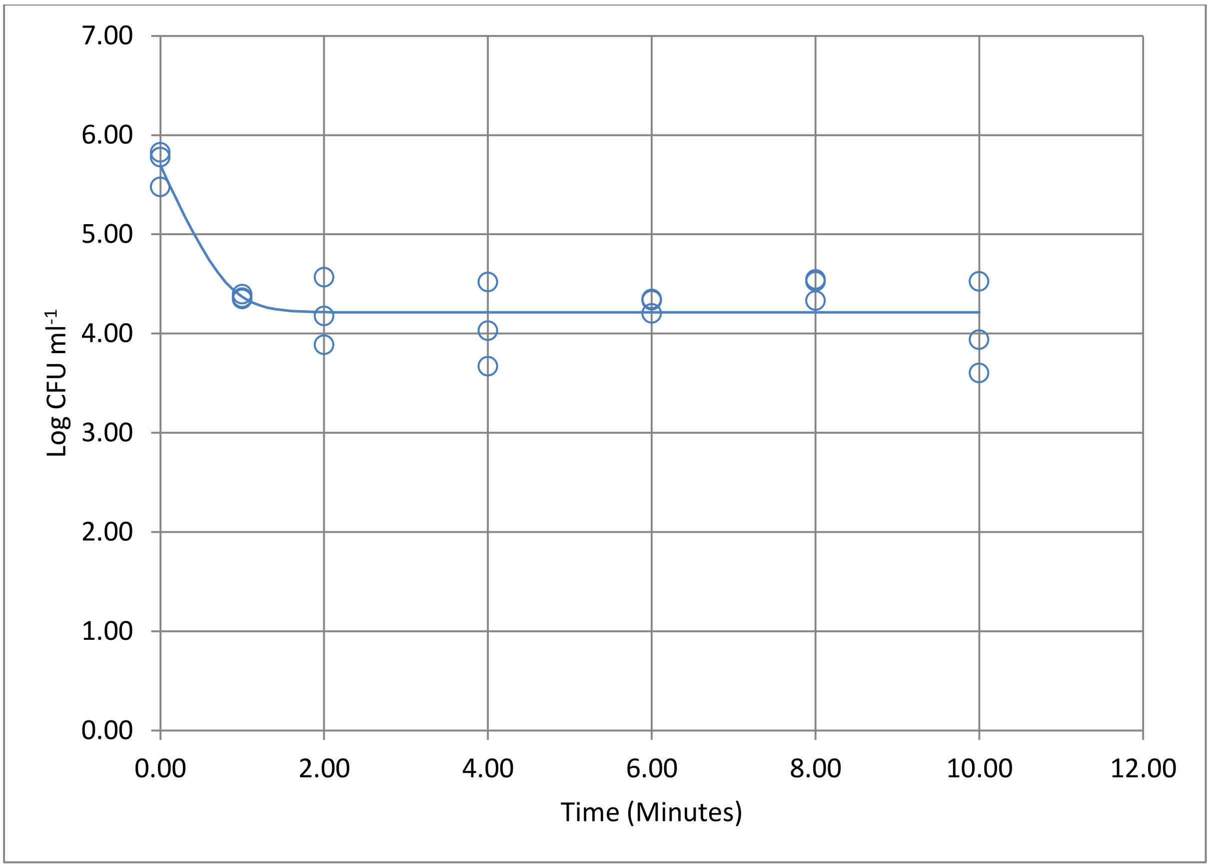

Figure 345. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following direct heating at 56°C.

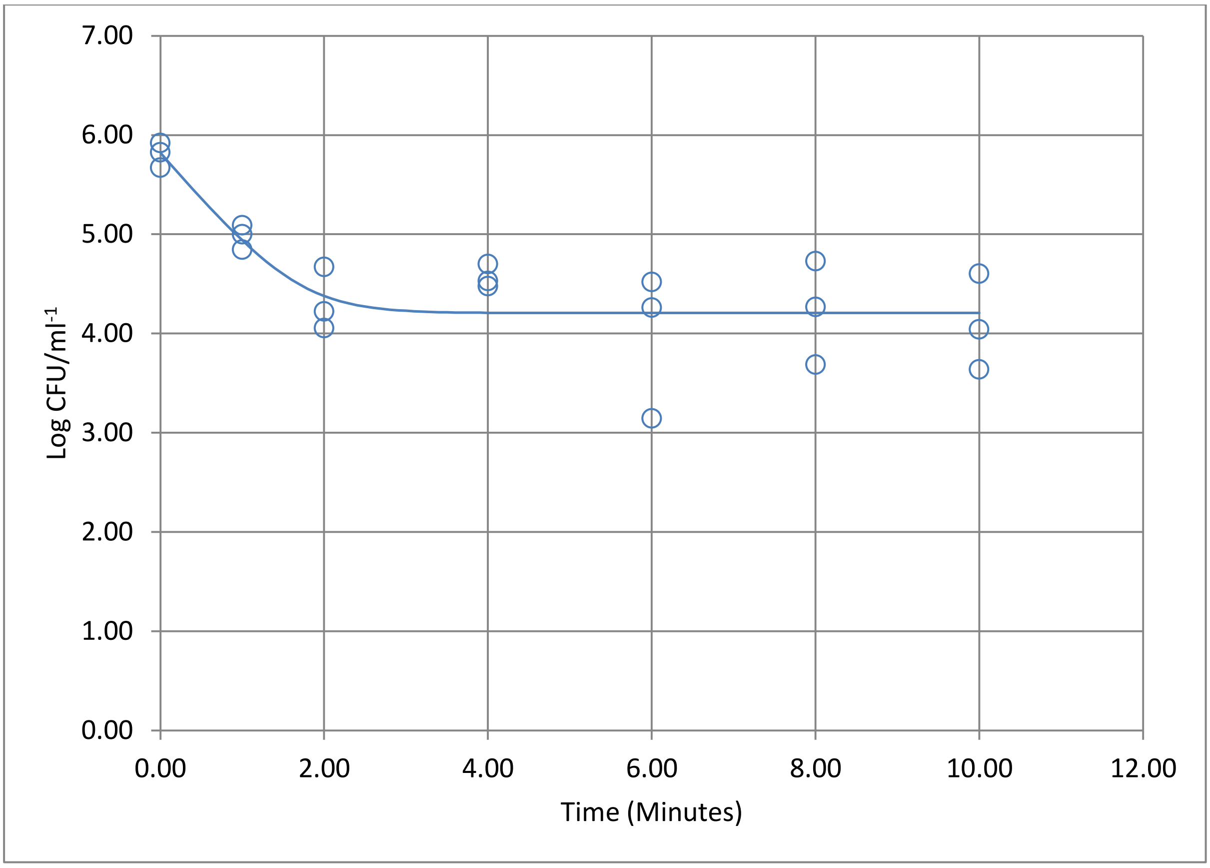

Figure 346. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following prior chilling and direct heating at 56°C.

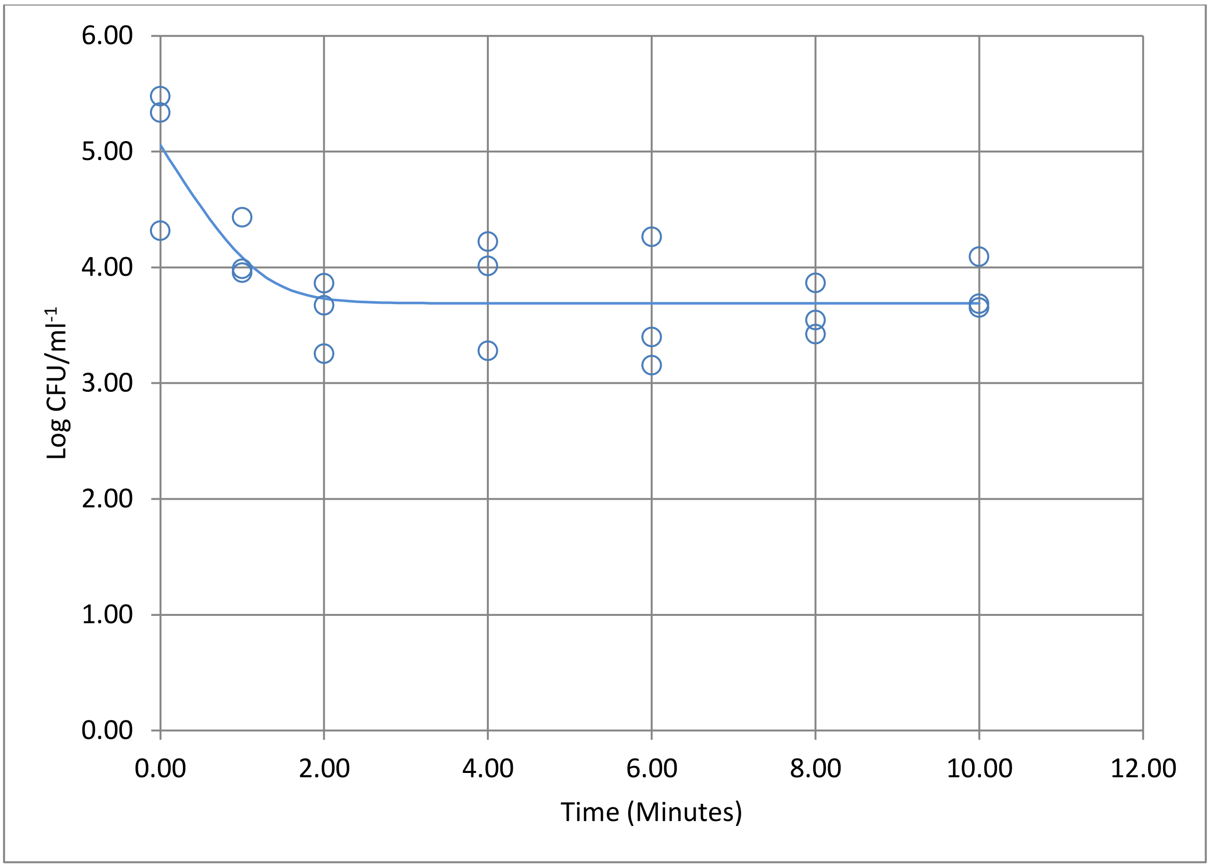

Figure 347. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following direct heating at 56°C.

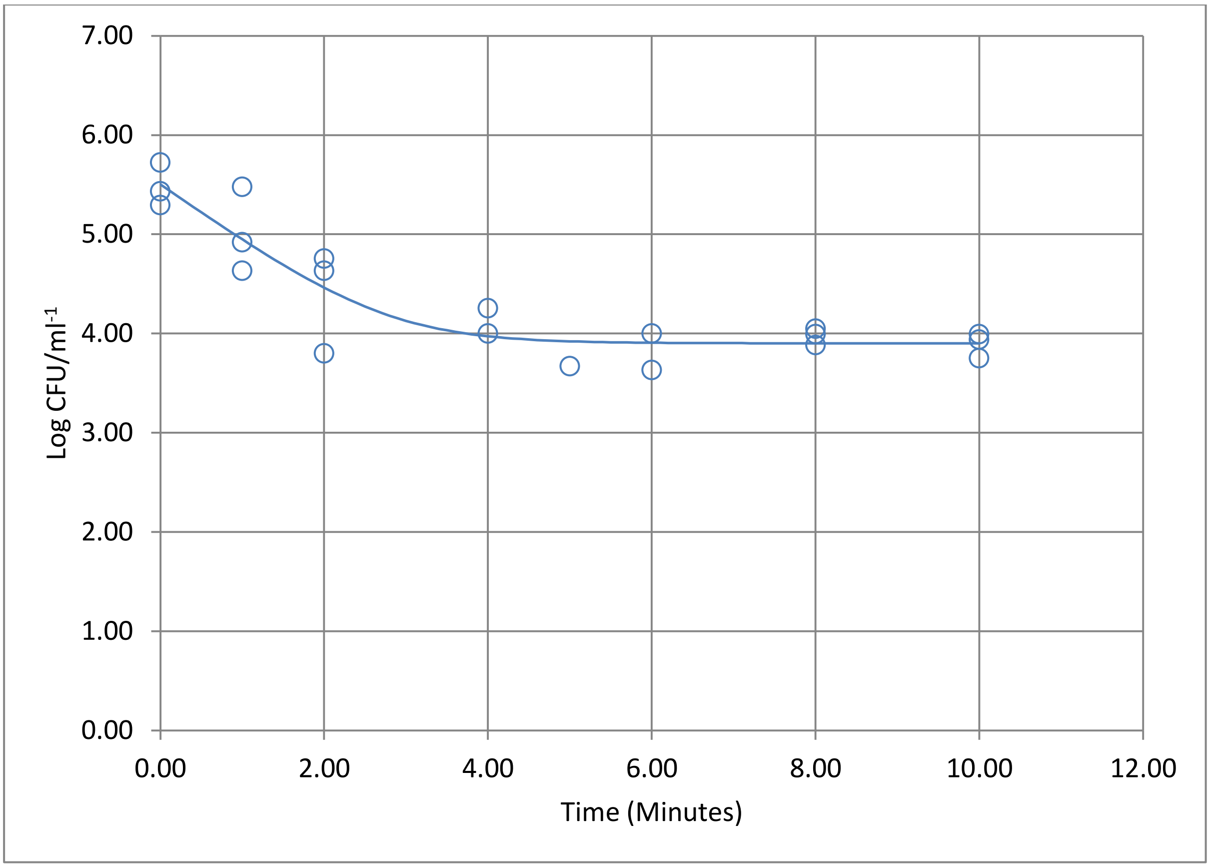

Figure 348. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 56°C.

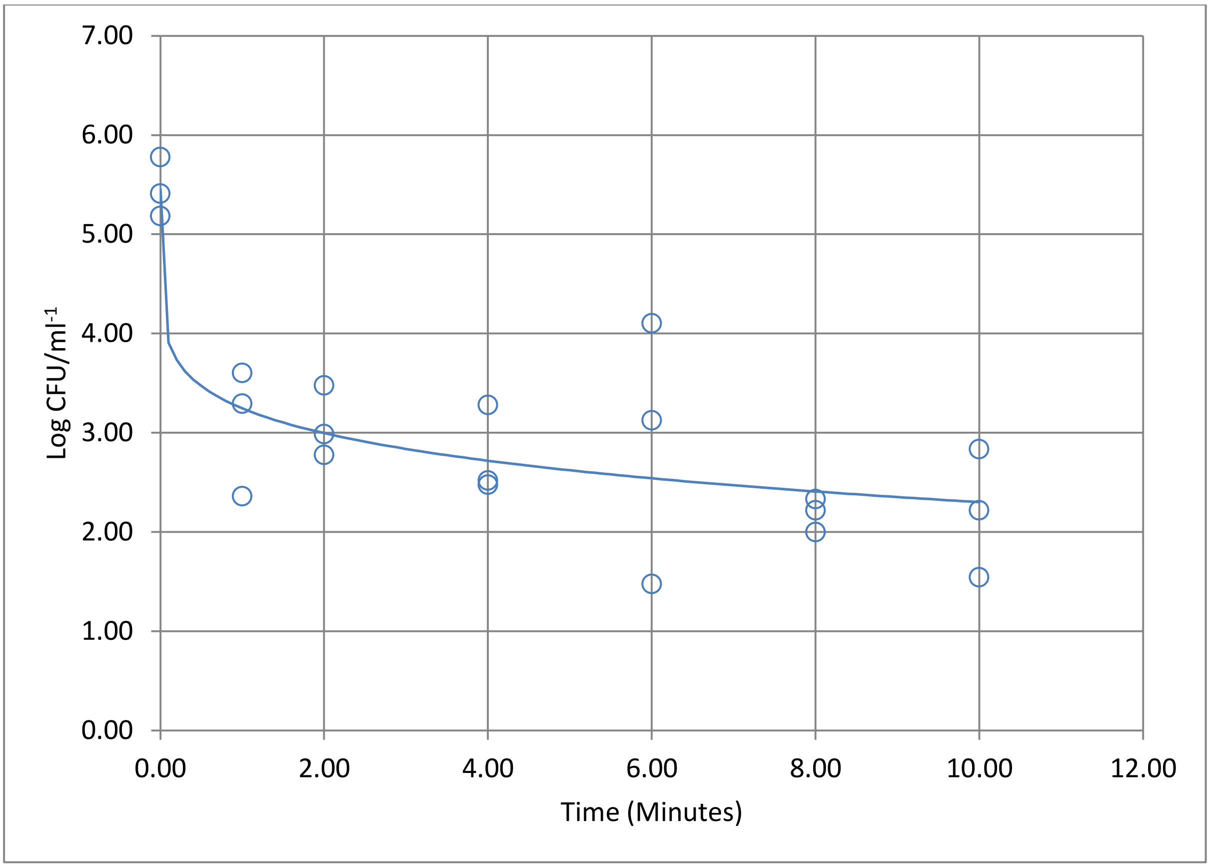

Figure 349. Plot illustrating predicted response curve using a Weibull model for strain 13126 (ST-21, CC-21) following direct heating at 56°C.

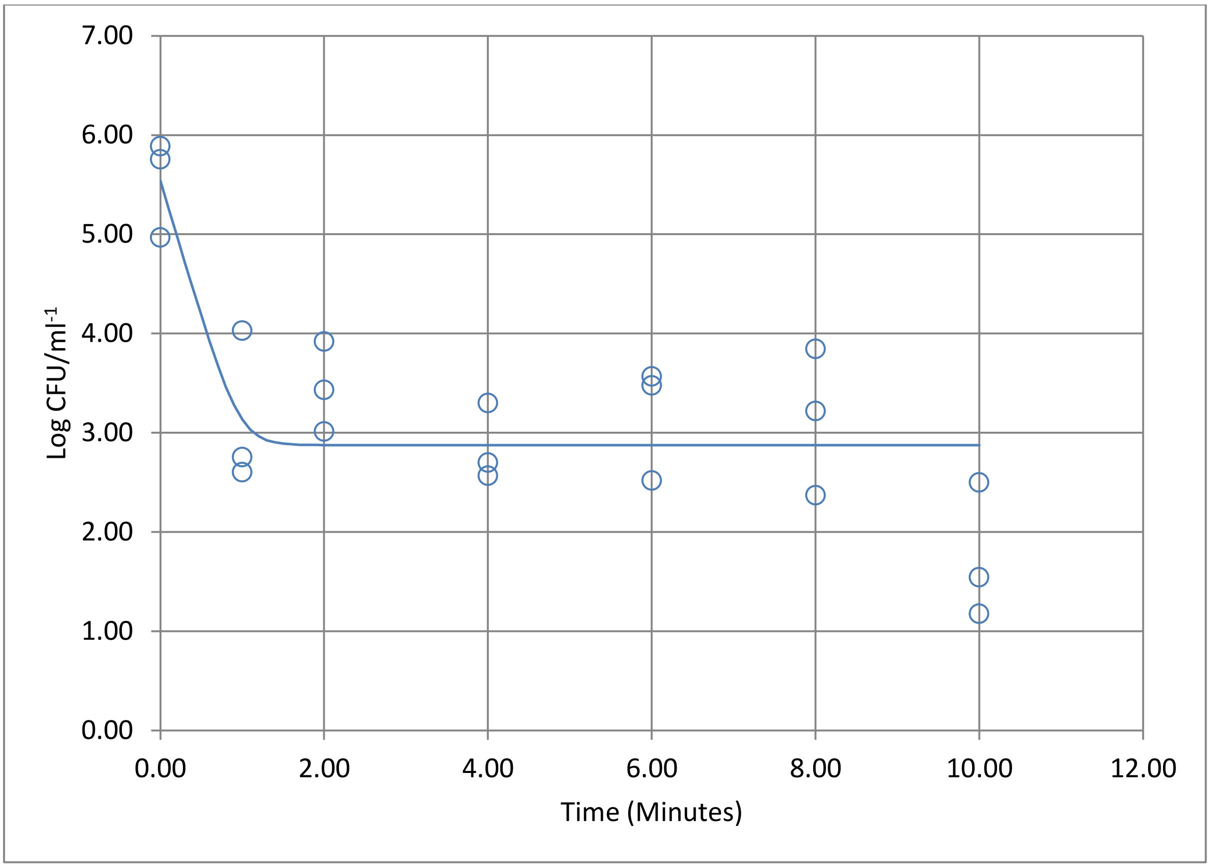

Figure 350. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 56°C.

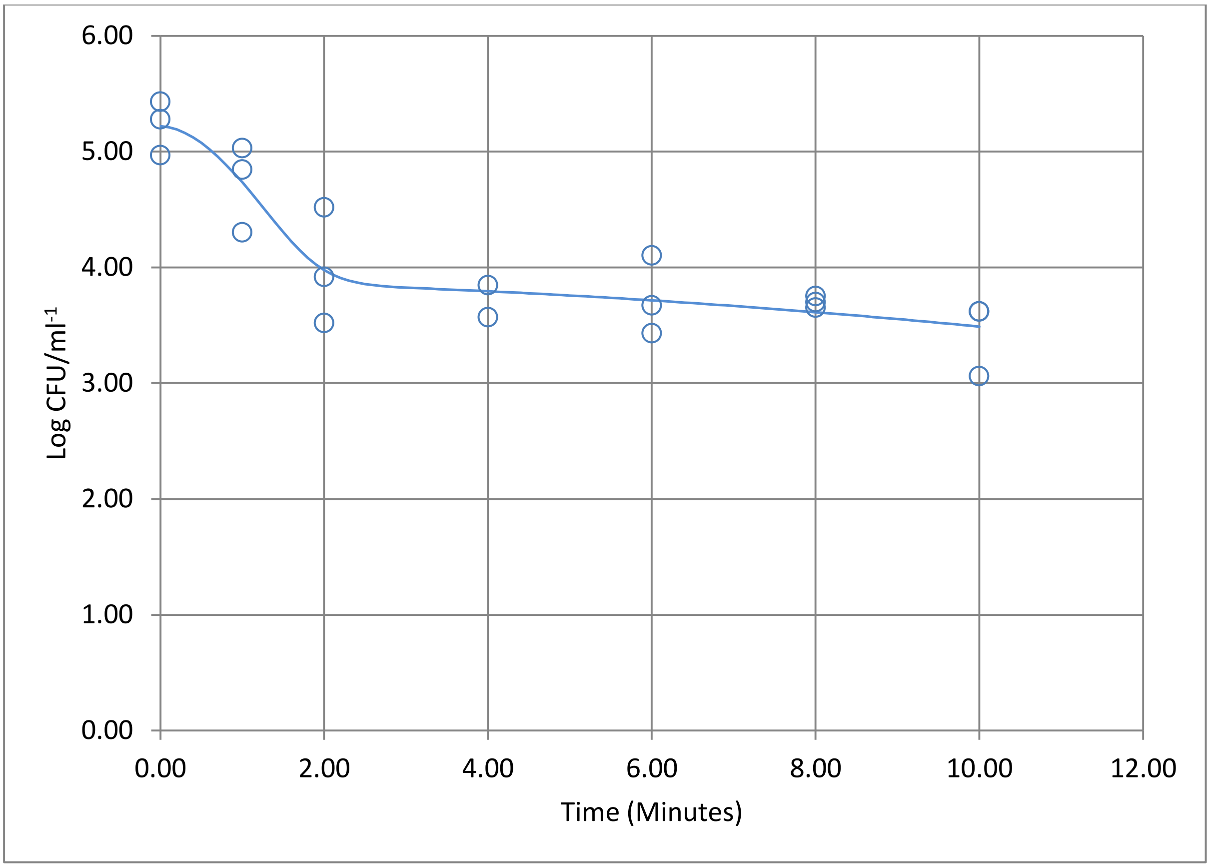

Figure 351. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13136 (ST-45, CC-45) following direct heating at 56°C.

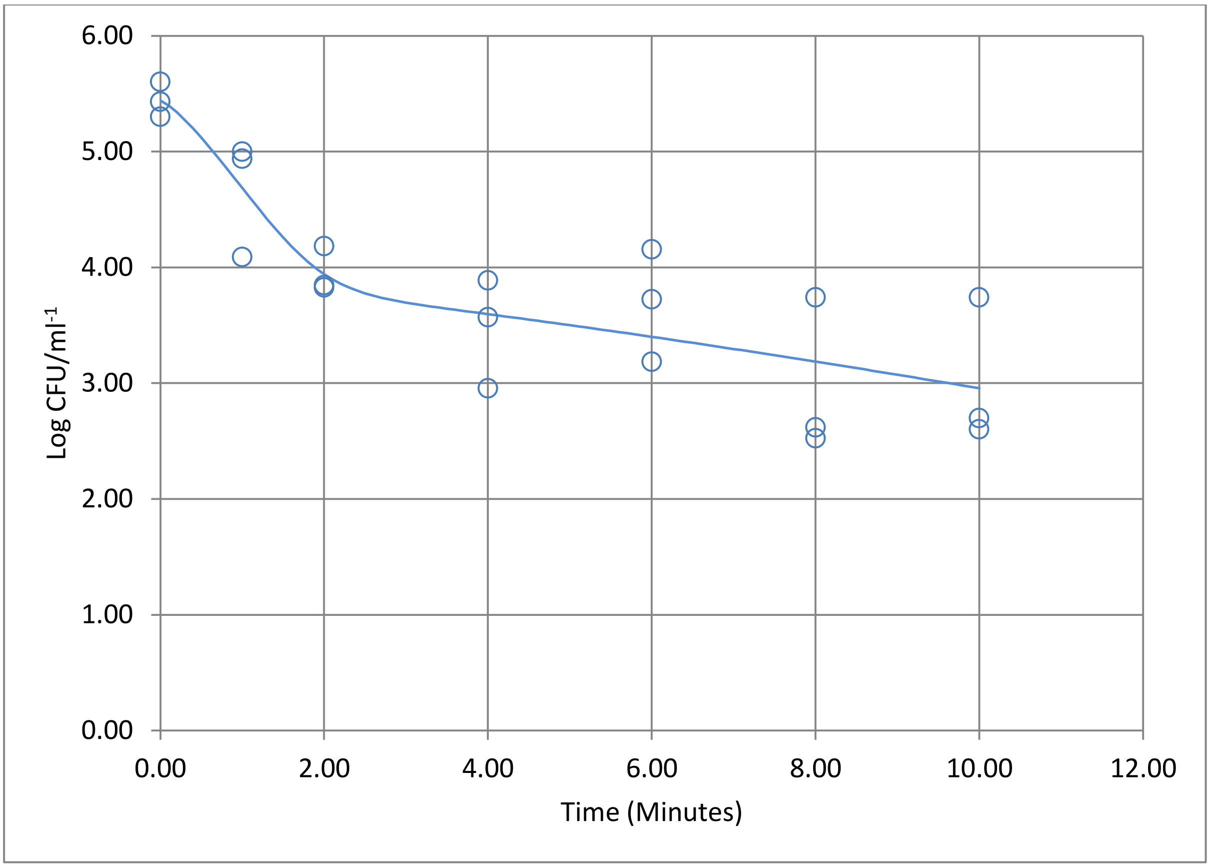

Figure 352. Plot illustrating predicted response curve using a mixed Weibull distribution model for strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 56°C.

2.3.23 Food-matrices Exterior Time-temperature Simulations: Direct Heating 60°C

Table 336. Assessment of model fit for individual strains following direct heating at 60°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	Direct Heat (Un-chilled)	0.346	0.743	0.129
12628 (ST-1773, CC-828)	Direct Heat (Pre-chilled)	0.362	0.762	1.160
12662 (ST-257, CC-257)	Direct Heat (Un-chilled)	0.339	0.771	0.380
12662 (ST-257, CC-257)	Direct Heat (Pre-chilled)	0.398	0.802	0.220
13126 (ST-21, CC-21)	Direct Heat (Un-chilled)	0.572	0.742	0.240
13126 (ST-21, CC-21)	Direct Heat (Pre-chilled)	0.371	0.829	0.292
13136 (ST-45, CC-45)	Direct Heat (Un-chilled)	0.293	0.878	0.023
13136 (ST-45, CC-45)	Direct Heat (Pre-chilled)	0.321	0.826	0.440

Table 337. Weibull model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following prior chilling and exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
Nres	4.079	0.805
δ	0.129	0.315
p	0.255	0.486
N0	5.871	0.200

Table 338. Log-linear model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following prior chilling and exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
Kmax	1.939	0.545
Nres	3.753	0.174
N0	5.428	0.176

Table 339. Biphasic model for survival of strain 12662 (ST-257, CC-257) following exposure to direct heat at 60°C.

Parameters	Estimates	Standard Error
F	0.961	0.029
Kmax1	7.108	2.663
Kmax2	0.243	0.212
N0	5.627	0.195

Table 340. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
Kmax	10.917	3.142
Nres	3.579	0.115
N0	5.732	0.230

Table 341. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
Kmax	9.465	2.463
Nres	3.220	0.167
N0	5.856	0.330

Table 342. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
Kmax	8.099	1.683
Nres	3.518	0.110
N0	5.719	0.214

Table 343. Weibull model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
δ	0.023	0.041
p	0.160	0.055
N0	5.444	0.169

Table 344. Biphasic model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following prior chilling and exposure to direct heating at 60°C.

Parameters	Estimates	Standard Error
F	0.962	0.028
Kmax1	6.007	1.892
Kmax2	0.374	0.217
N0	5.223	0.185

2.3.24 Predicted Response Curves: Food Matrix Exterior Time-Temperature Profile Direct Heating 60°C

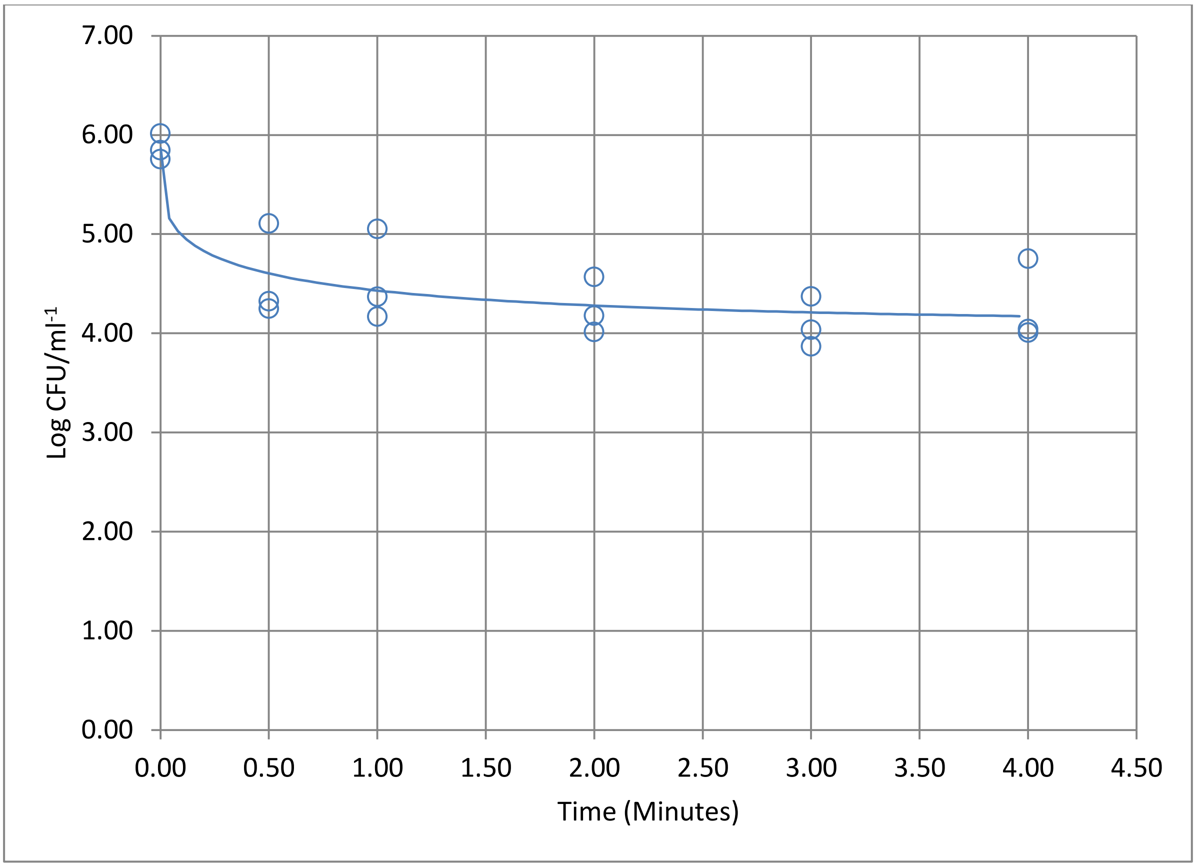

Figure 353. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following direct heating at 60°C.

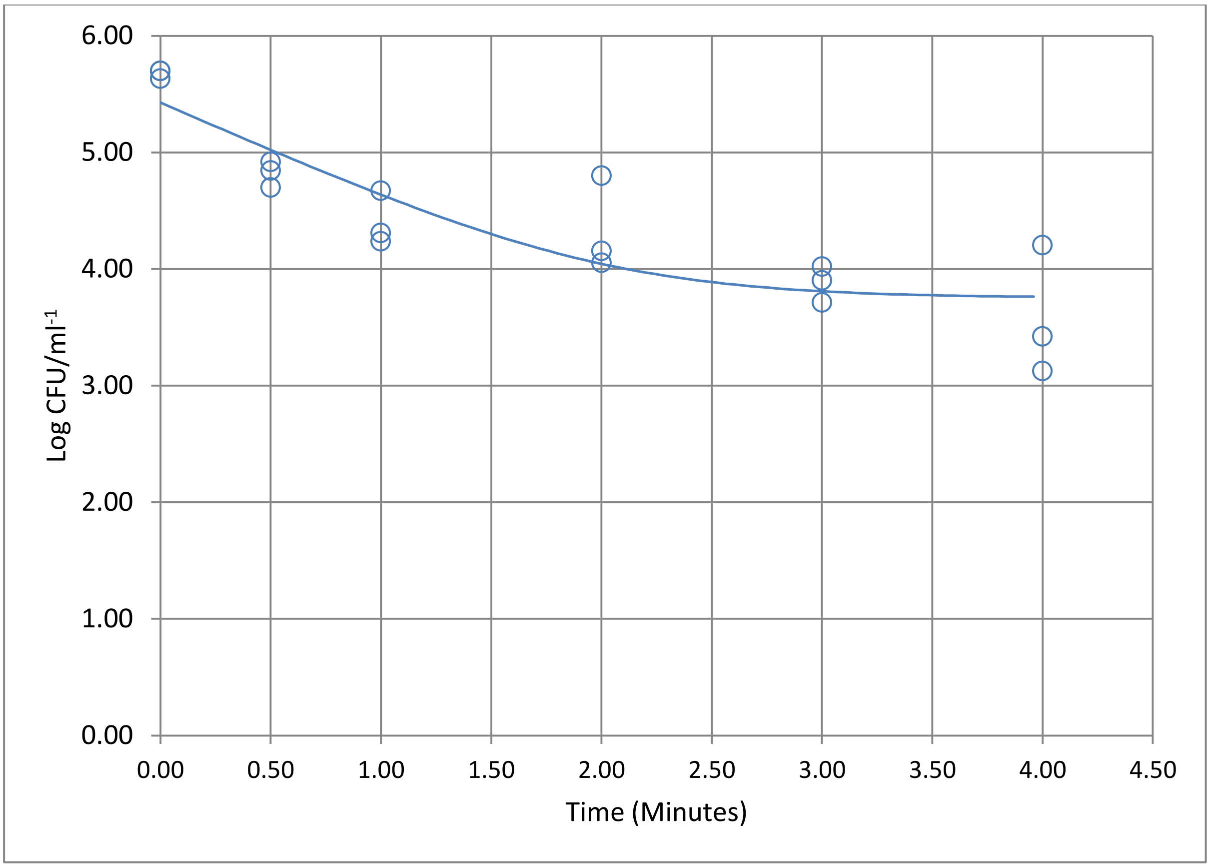

Figure 354. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following prior chilling and direct heating at 60°C.

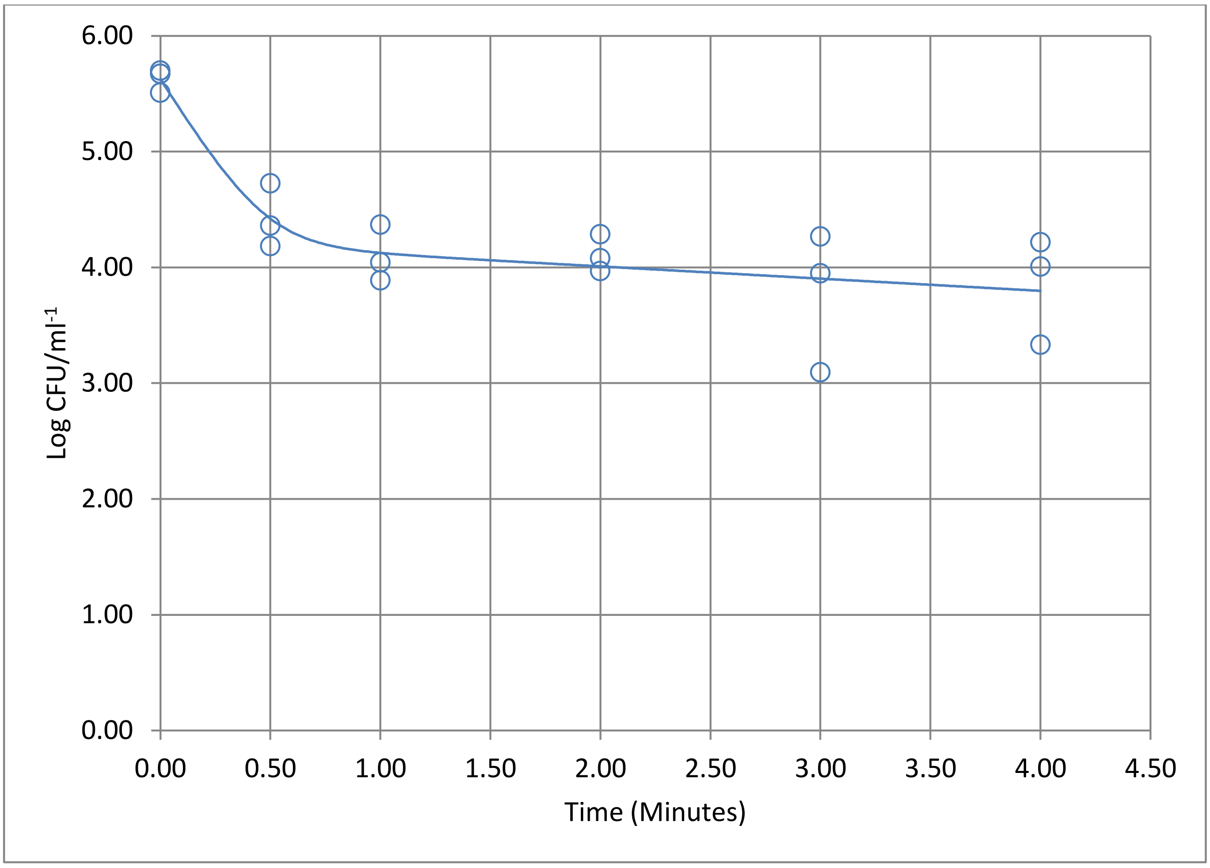

Figure 355. Plot illustrating predicted response curve using a Biphasic model for strain 12662 (ST-257, CC-257) following direct heating at 60°C.

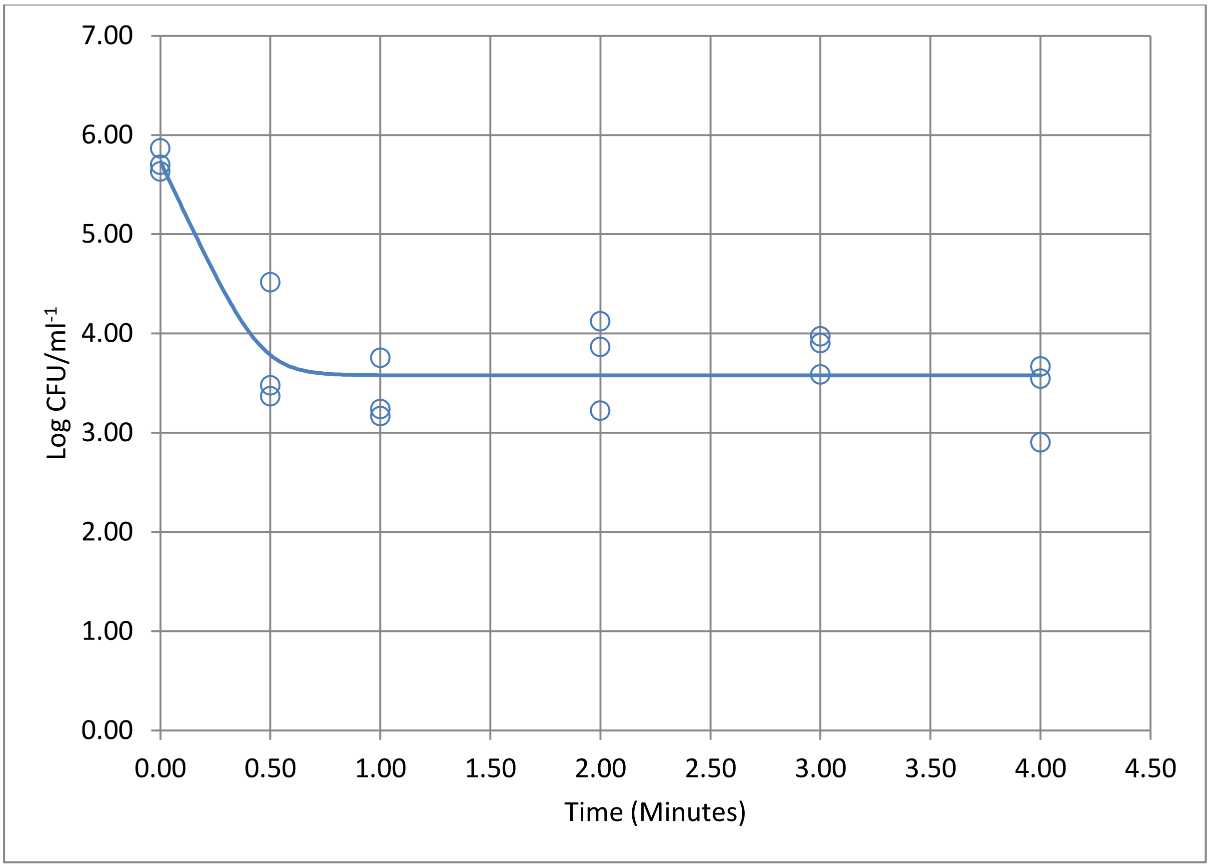

Figure 356. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12662 (ST-45, CC-45) following prior chilling and direct heating at 60°C.

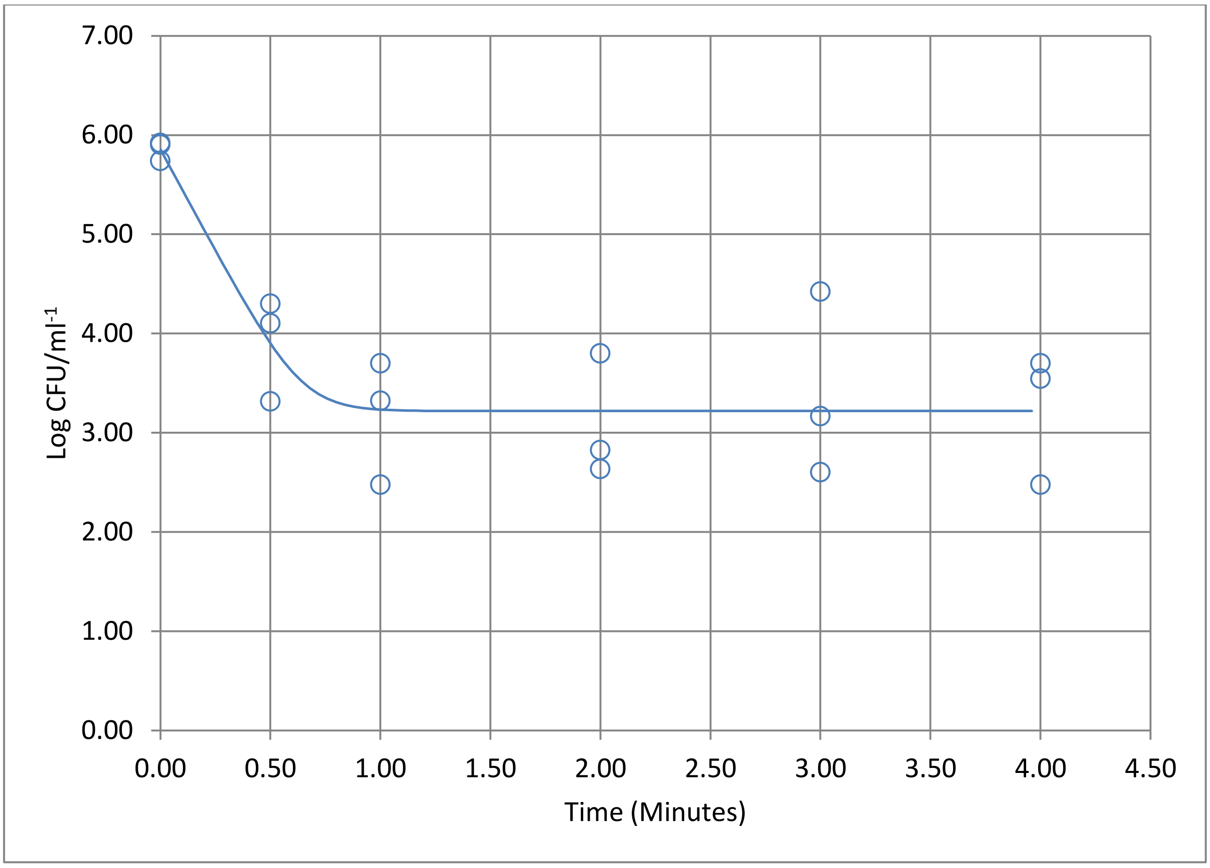

Figure 357. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following direct heating at 60°C.

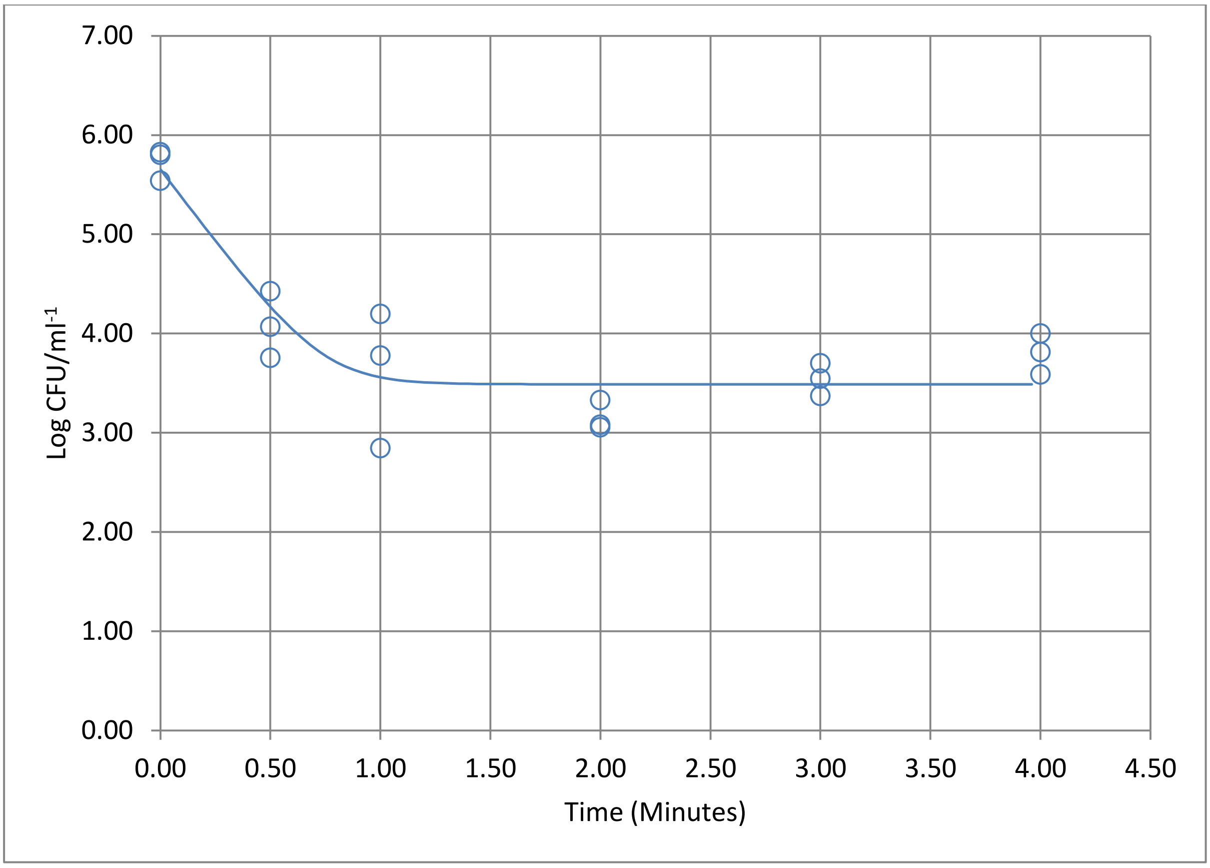

Figure 358. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 60°C.

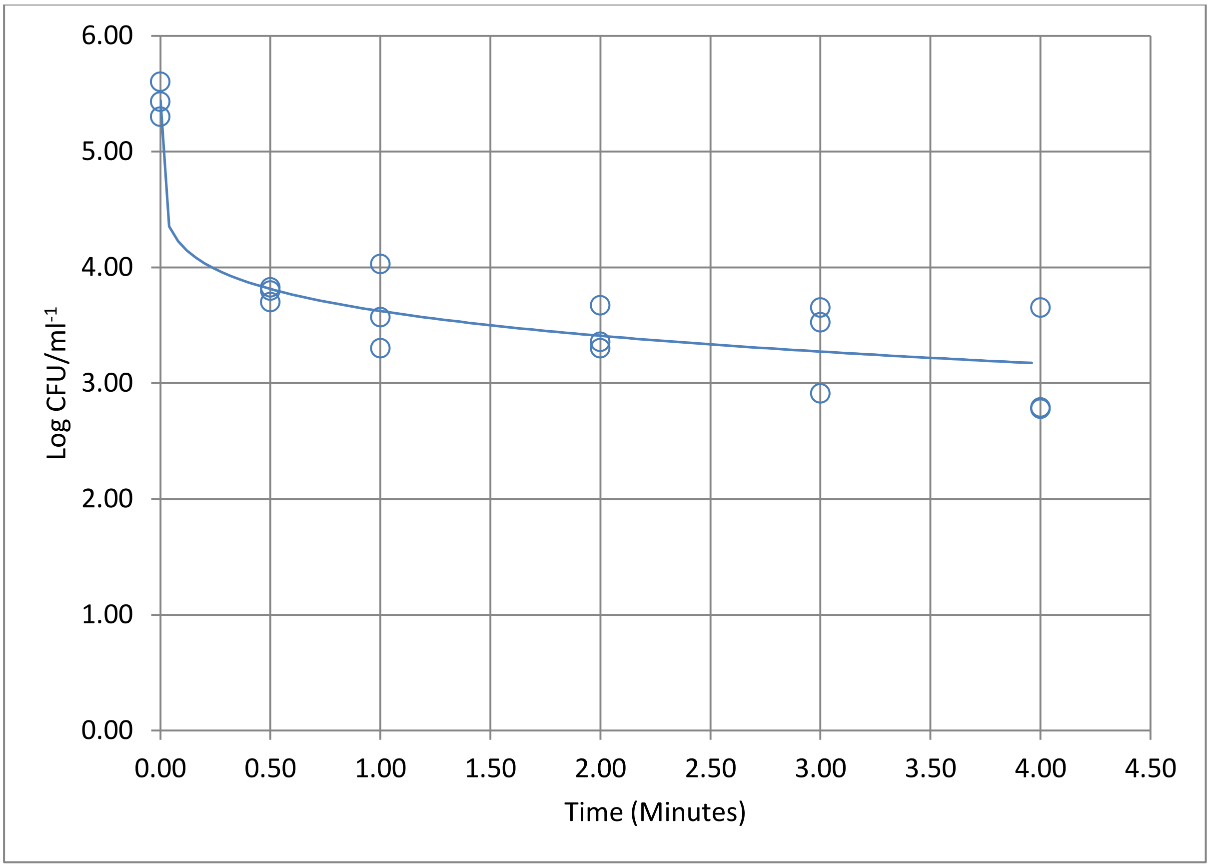

Figure 359. Plot illustrating predicted response curve using a Weibull model for strain 13136 (ST-45, CC-45) following direct heating at 60°C.

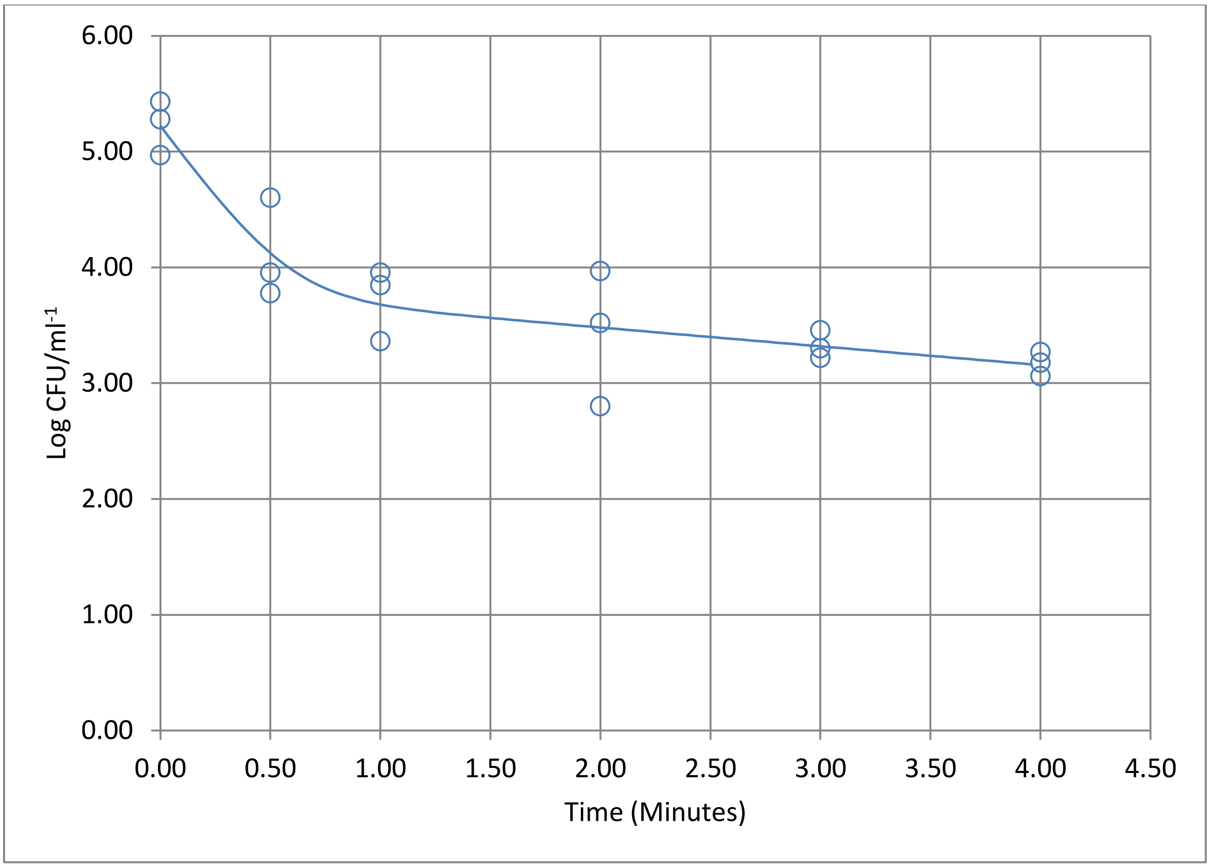

Figure 360. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 60°C.

2.3.25 Food-matrices Exterior Time-temperature Simulations: Direct Heating 64°C

Table 345. Assessment of model fit for individual strains following direct heating at 64°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12662 ST-257, CC-257	Direct Heat (Un-chilled)	0.384	0.935	0.230
12662 ST-257, CC-257	Direct Heat (Pre-chilled)	0.375	0.876	0.140
13126 (ST-21, CC-21)	Direct Heat (Un-chilled)	0.515	0.880	0.130
13126 (ST-21, CC-21)	Direct Heat (Pre-chilled)	0.375	0.947	0.033
13136 (ST-45, CC-45)	Direct Heat (Un-chilled)	0.606	0.797	0.056
13136 (ST-45, CC-45)	Direct Heat (Pre-chilled)	0.623	0.799	0.001

Table 346. Biphasic model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following direct heating at 64°C.

Parameters	Estimates	Standard Error
F	0.999	0.001
Kmax1	10.176	2.342
Kmax2	0.628	0.239
N0	5.719	0.221

Table 347. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 64°C.

Parameters	Estimates	Standard Error
Kmax	16.035	4.184
Nres	2.487	0.138
N0	5.647	0.264

Table 348. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following direct heating at 64°C.

Parameters	Estimates	Standard Error
Kmax	17.298	4.174
Nres	2.094	0.163
N0	5.614	0.297

Table 349. Weibull model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 64^{o}C.

Parameters	Estimates	Standard Error
Nres	1.761	0.233
δ	0.013	0.033
p	0.310	0.199
N0	5.715	0.216

Table 350. Weibull model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following direct heating at 64^{o}C.

Parameters	Estimates	Standard Error
Nres	1.828	0.893
δ	0.056	0.109
p	0.329	0.213
N0	5.461	0.350

Table 351. Weibull model for survival of strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 64^{o}C.

Parameters	Estimates	Standard Error
δ	0.001	0.004
p	0.148	0.084
N0	5.701	0.360

2.3.26 Food-matrices Time-temperature Simulations: Direct Heating 64°C

Predicted Response Curves:

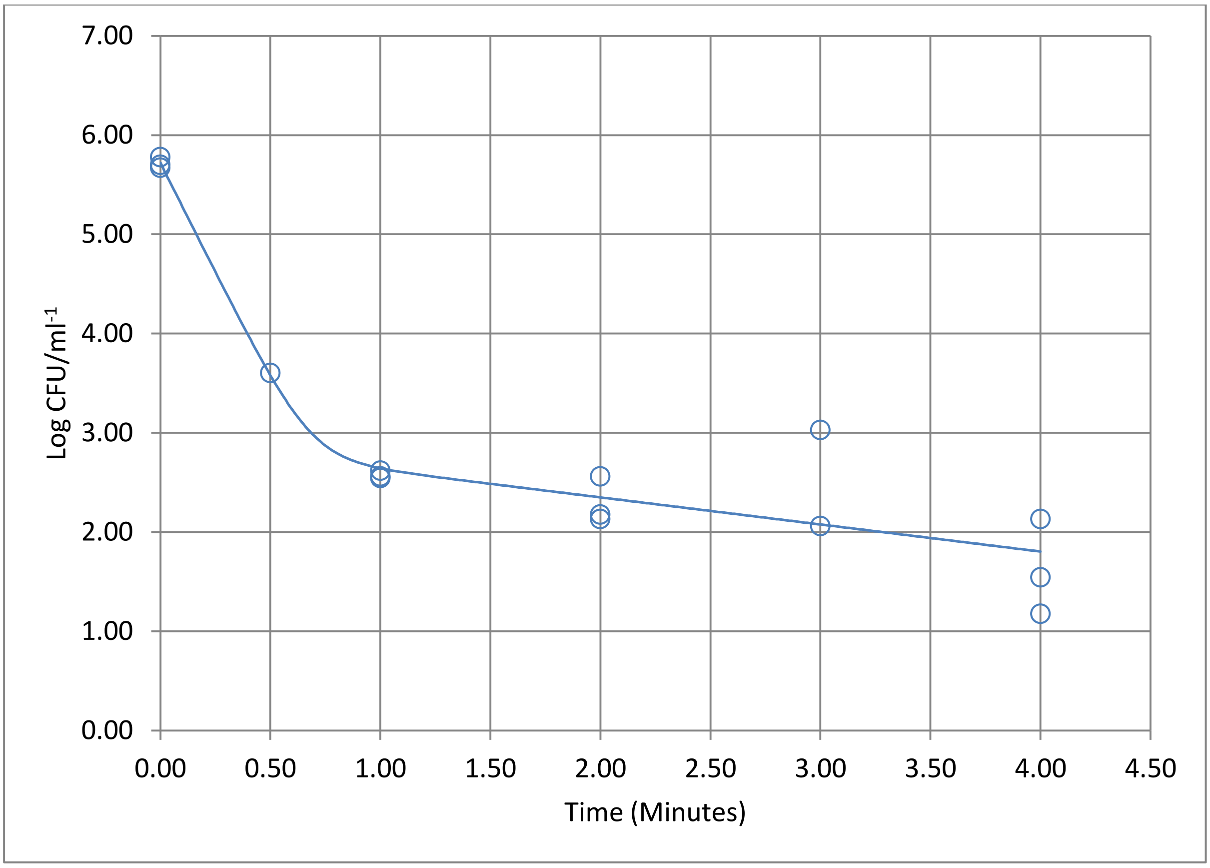

Figure 361. Plot illustrating predicted response curve using a biphasic model for strain 12662 (ST-257, CC-257) following direct heating at 64°C.

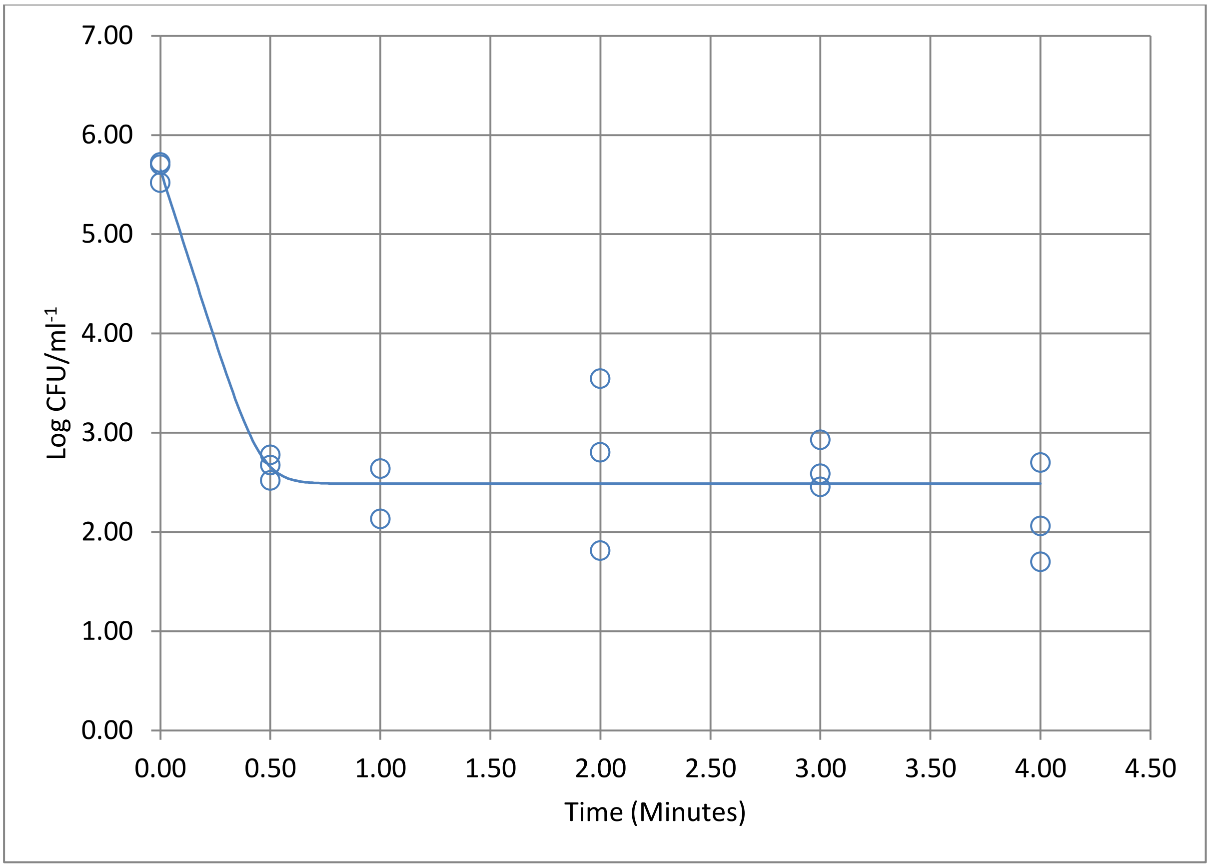

Figure 362. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following direct heating at 64°C.

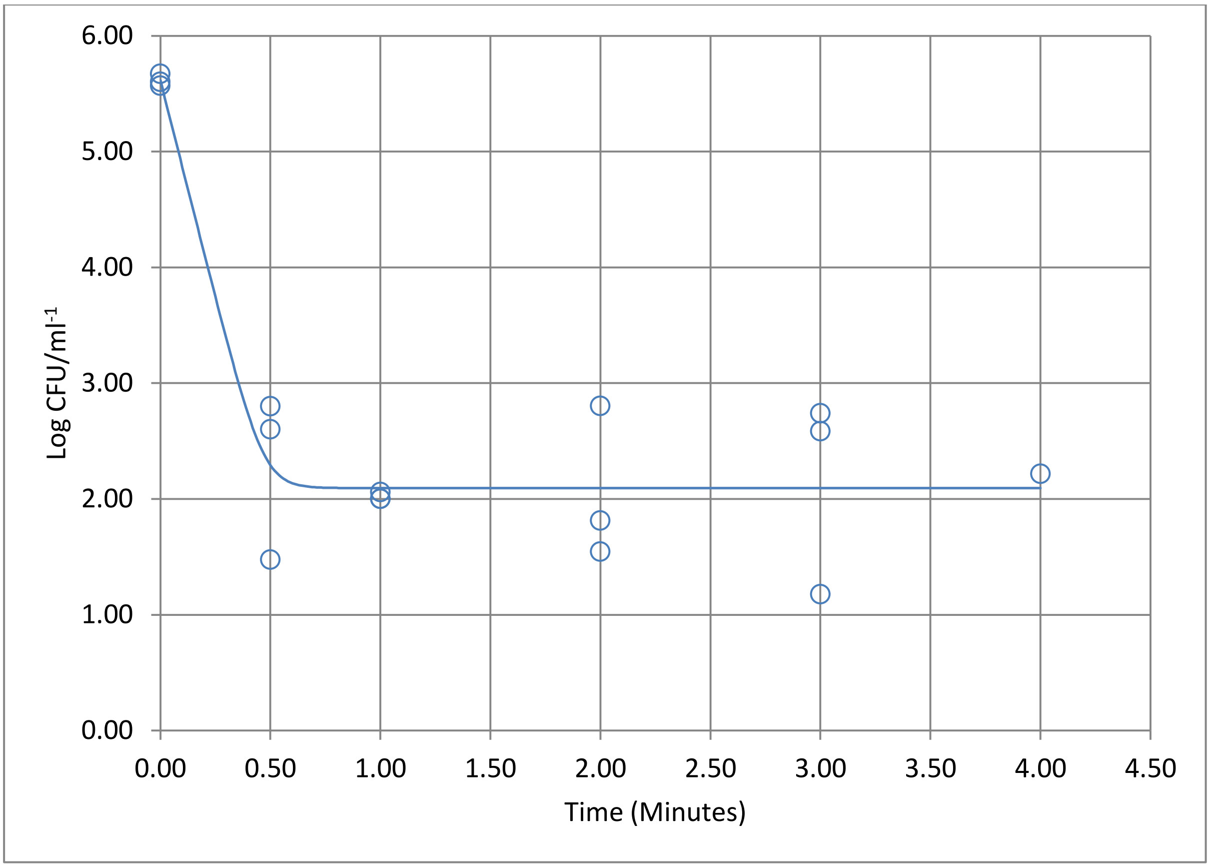

Figure 363. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following direct heating at 64°C.

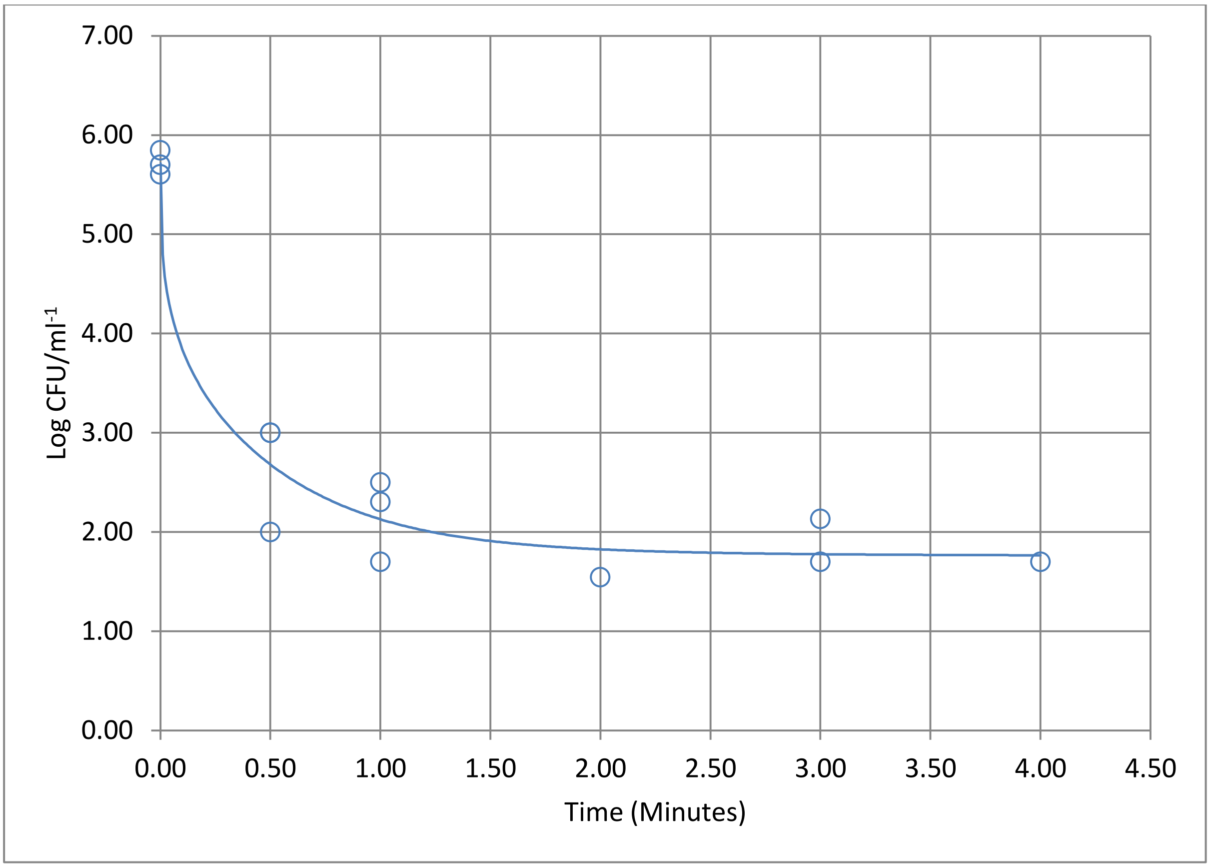

Figure 364. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 64°C.

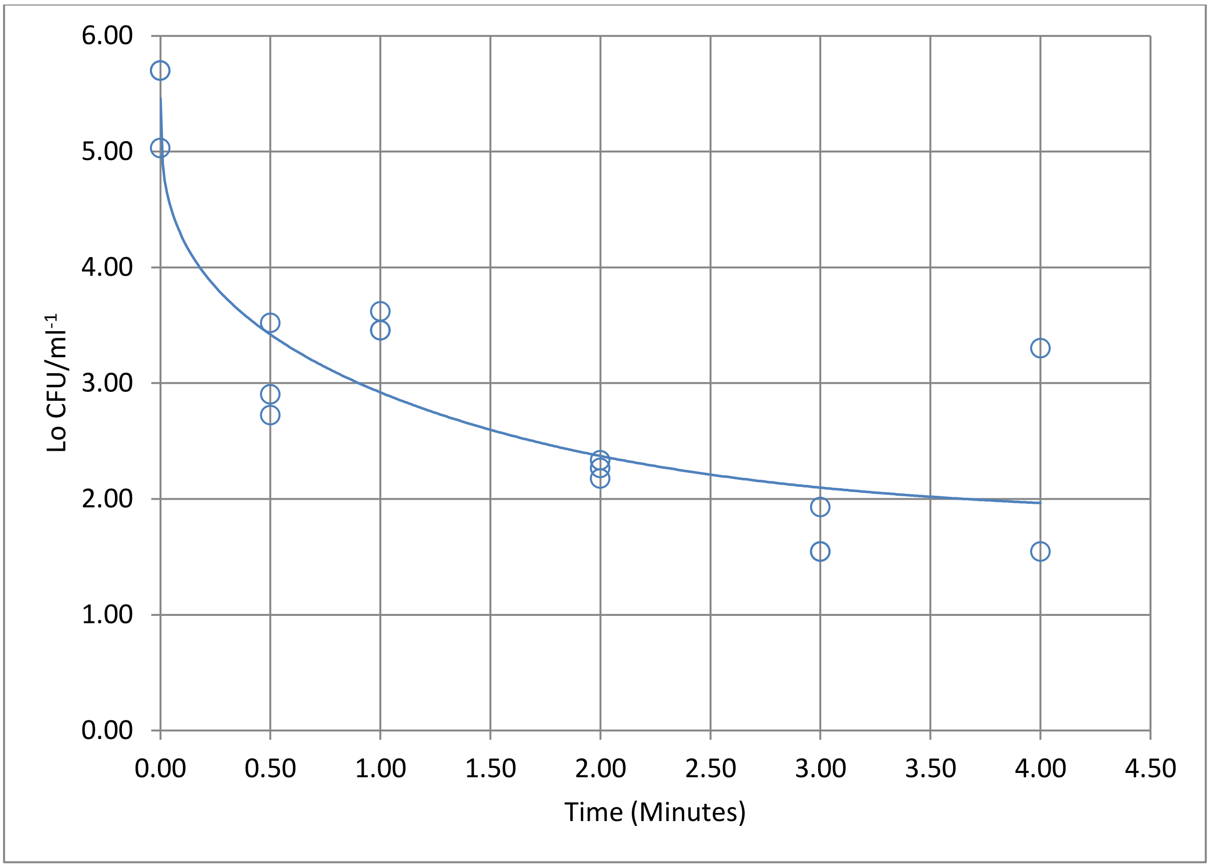

Figure 365. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following direct heating at 64°C.

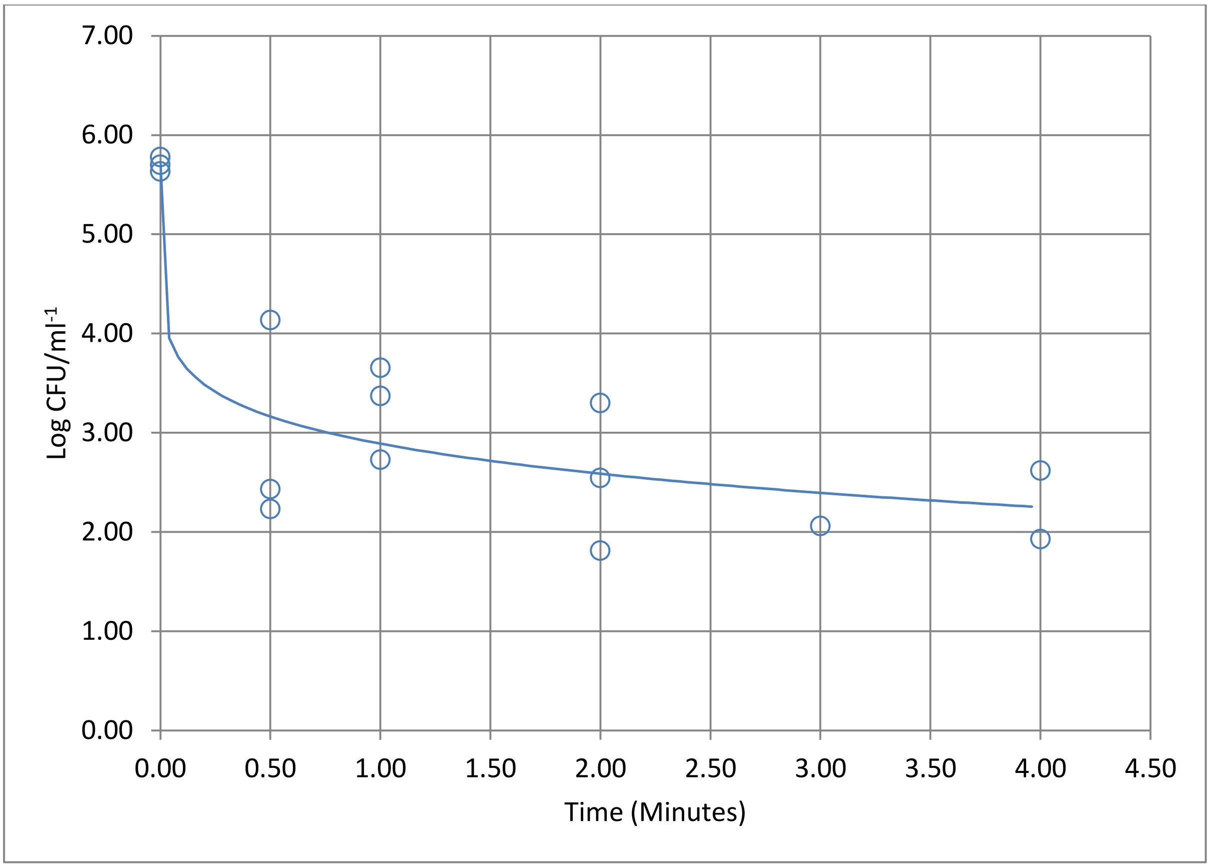

Figure 366. Plot illustrating predicted response curve using a Weibull model for strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 64°C.

2.3.27 Food-matrices Exterior Time-temperature Simulations: Direct Heating 68°C

Table 352. Assessment of individual model fit for strains following direct heating at 68°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12662 ST-257, CC-257	Direct Heat (Un-chilled)	0.231	0.956	0.054
12662 ST-257, CC-257	Direct Heat (Pre-chilled)	0.384	0.889	0.128
13126 (ST-21, CC-21)	Direct Heat (Un-chilled)	0.589	0.831	0.000
13126 (ST-21, CC-21)	Direct Heat (Pre-chilled)	0.347	0.936	0.090
13136 (ST-45, CC-45)	Direct Heat (Un-chilled)	0.708	0.675	0.100
13136 (ST-45, CC-45)	Direct Heat (Pre-chilled)	0.380	0.925	0.150

Table 353. Weibull model for survival of strain 12662 (ST-257, CC-257) following direct heating at 68°C.

Parameters	Estimates	Standard Error
δ	0.054	0.047
p	0.294	0.080
N0	5.713	0.133

Table 354. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 68°C.

Parameters	Estimates	Standard Error
Kmax	18.226	43.047
Nres	3.297	0.157
N0	5.728	0.222

Table 355. Weibull model for survival of strain 13126 (ST-21, CC-21) following direct heating at 68°C.

Parameters	Estimates	Standard Error
Kmax	0.000	0.001
Nres	0.130	0.060
N0	5.400	0.340

Table 356. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and exposure to direct heating at 68^{o}C.

Parameters	Estimates	Standard Error
Kmax	25.596	2.819
Nres	2.112	0.097
N0	5.713	0.200

Table 357. Log-linear model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following direct heating at 68^{o}C.

Parameters	Estimates	Standard Error
Kmax	21.729	6.595
Nres	2.736	0.215
N0	5.477	0.409

Table 358. Log-linear model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 68^{o}C.

Parameters	Estimates	Standard Error
Kmax	15.667	1.972
Nres	2.221	0.125
N0	5.708	0.206

2.3.28 Food-matrices Exterior Time-Temperature Simulations: Direct Heating 68°C

Predicted Response Curves:

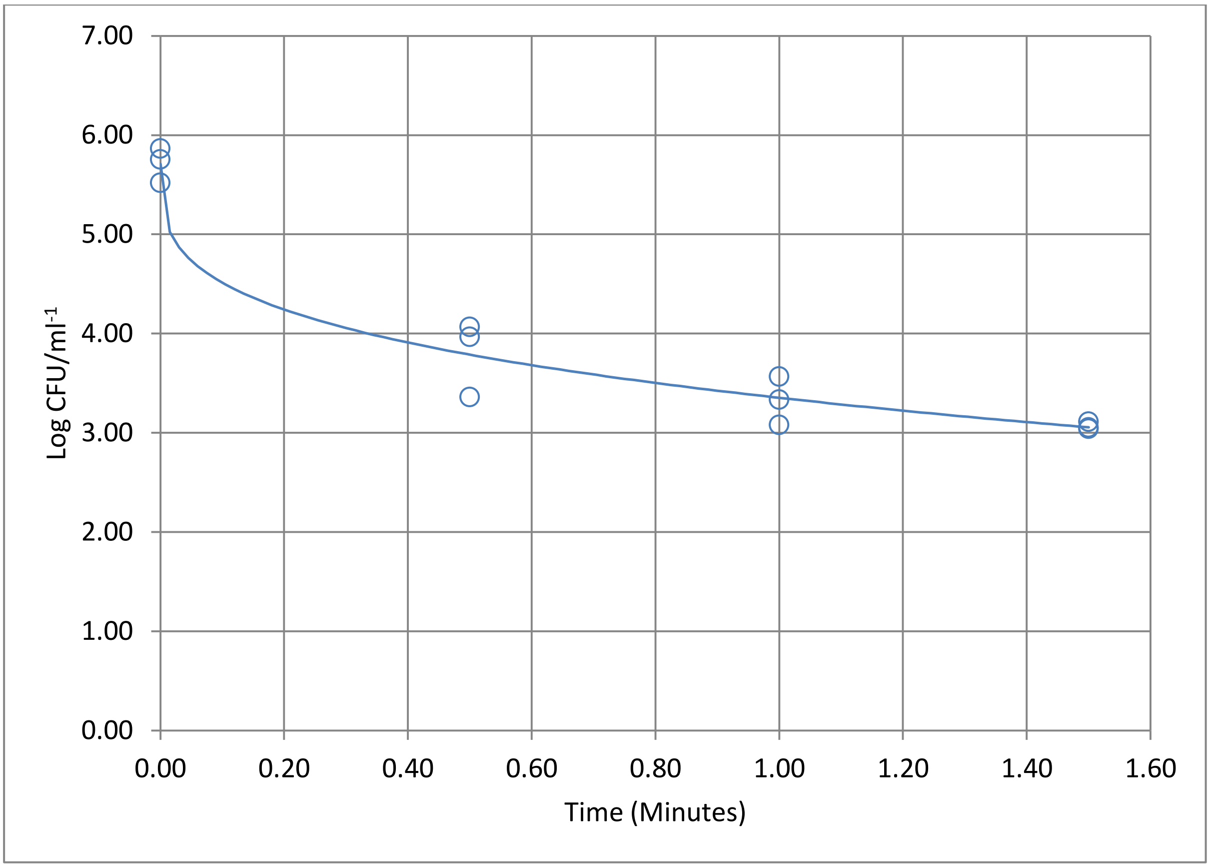

Figure 367. Plot illustrating predicted response curve using a Weibull model for strain 12662 (ST-257, CC-257) following direct heating at 68°C.

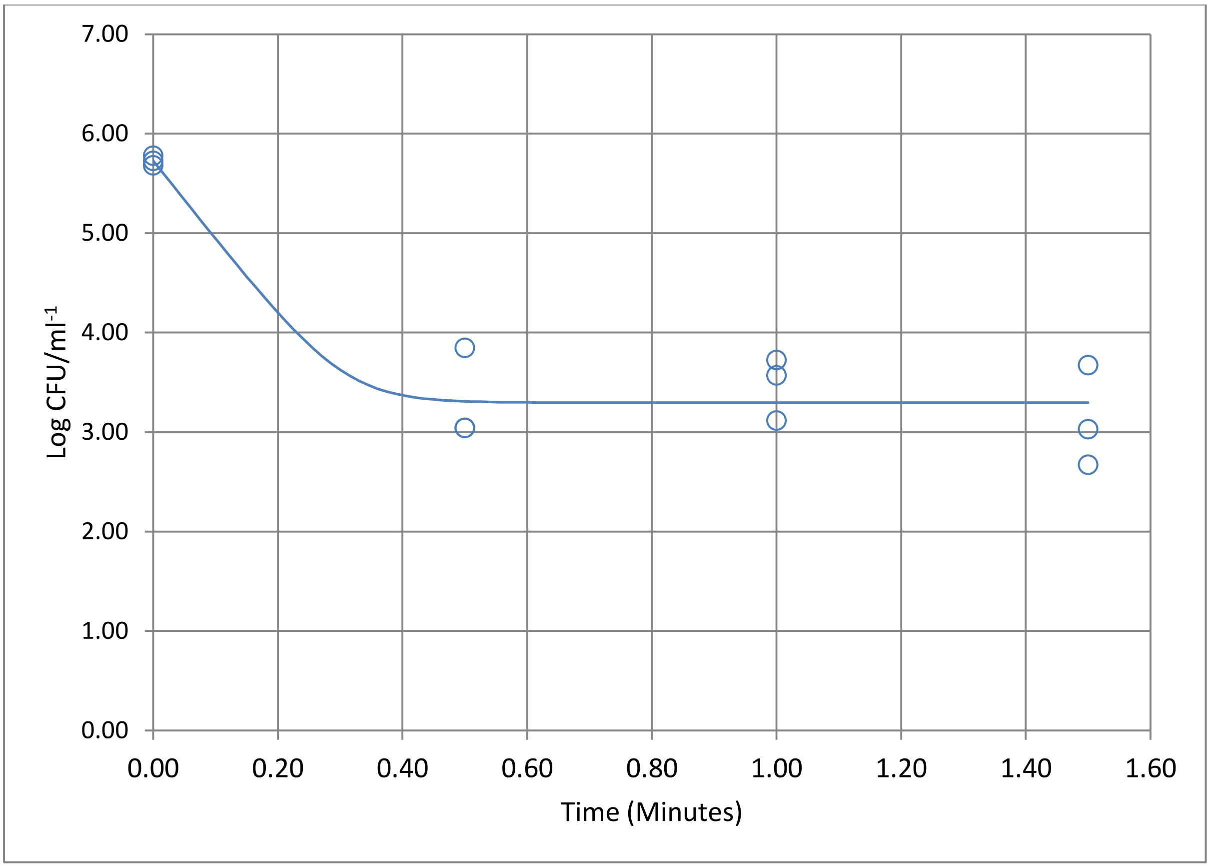

Figure 368. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 68°C.

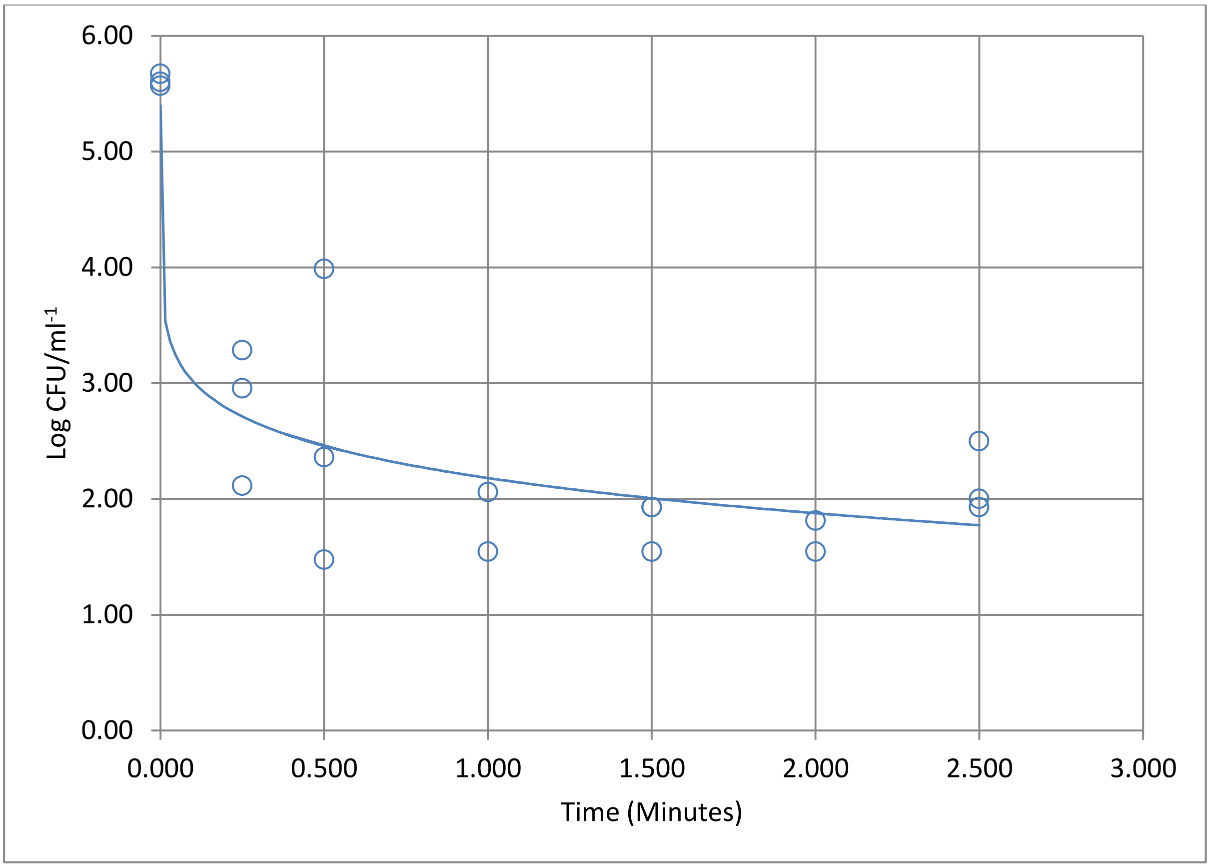

Figure 369. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following direct heating at 68°C.

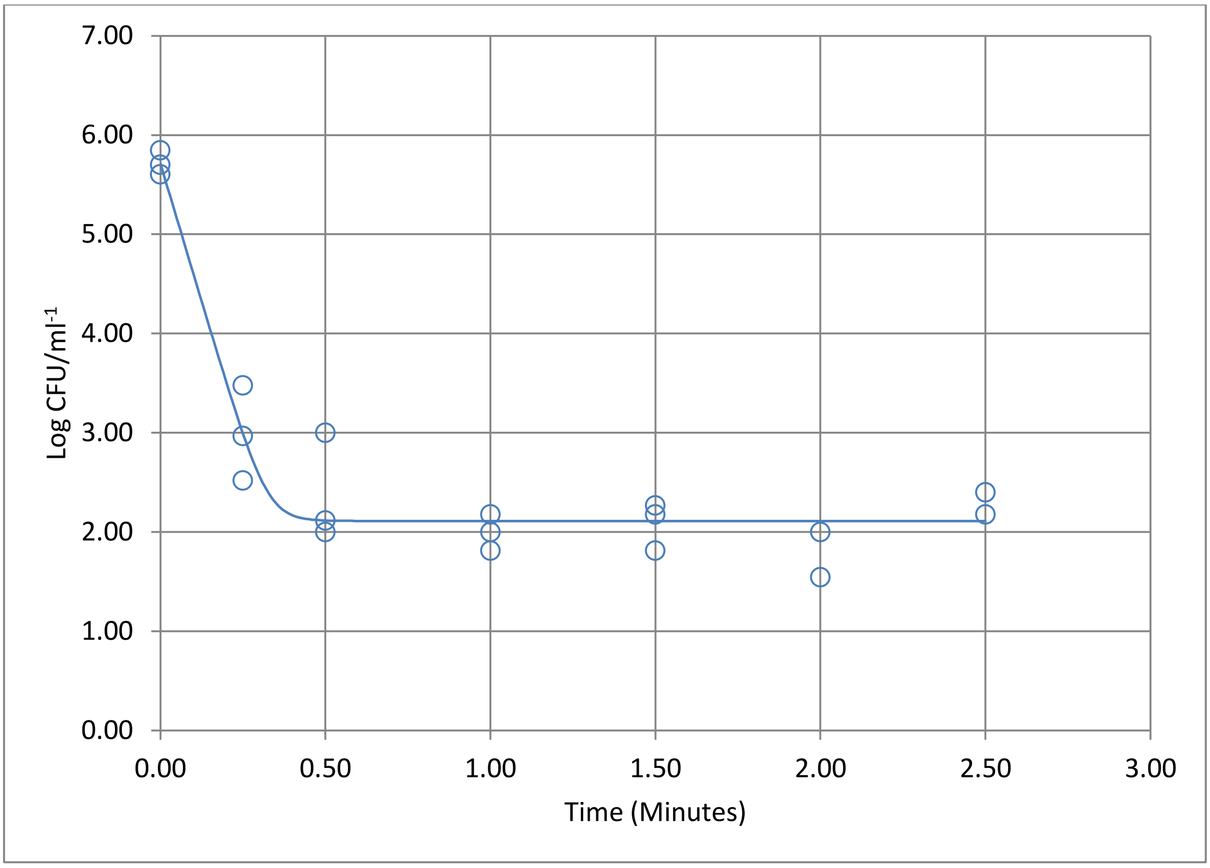

Figure 370. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 68°C.

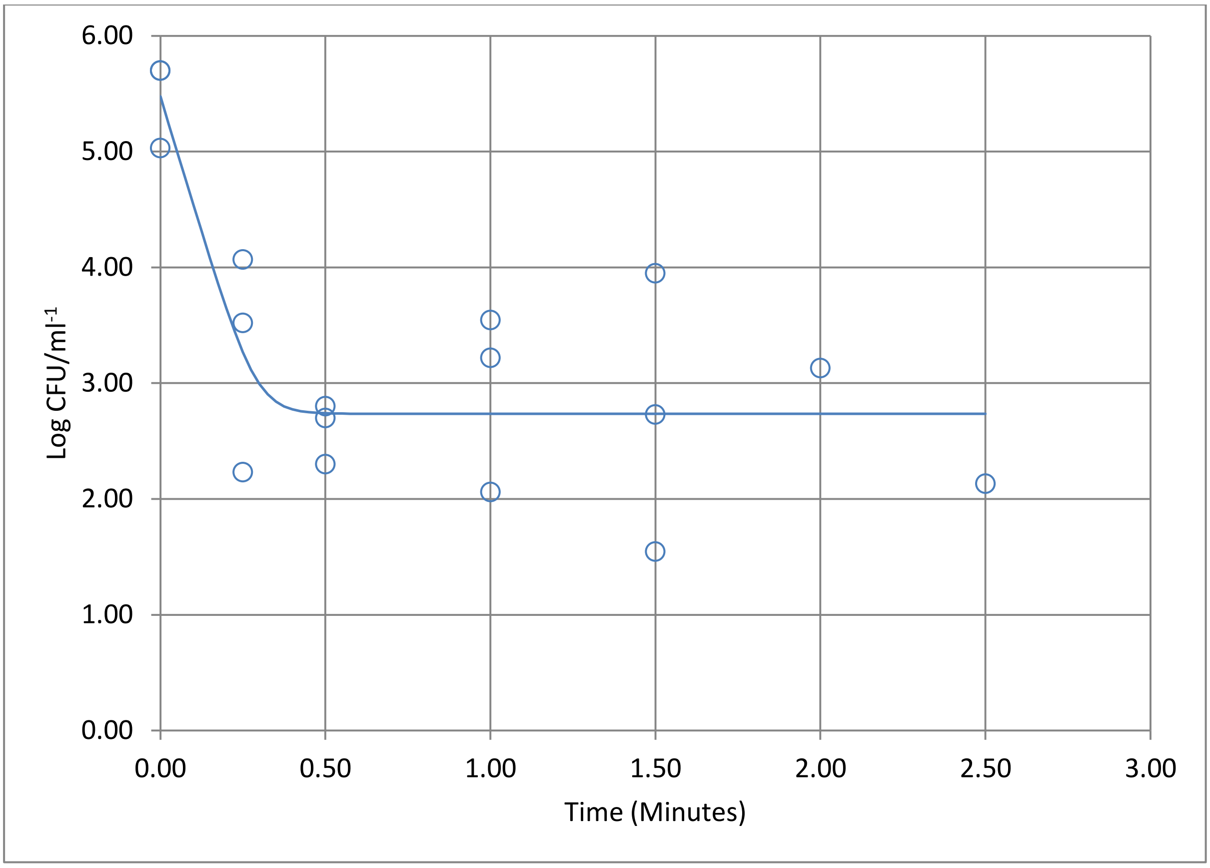

Figure 371. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following direct heating at 68°C.

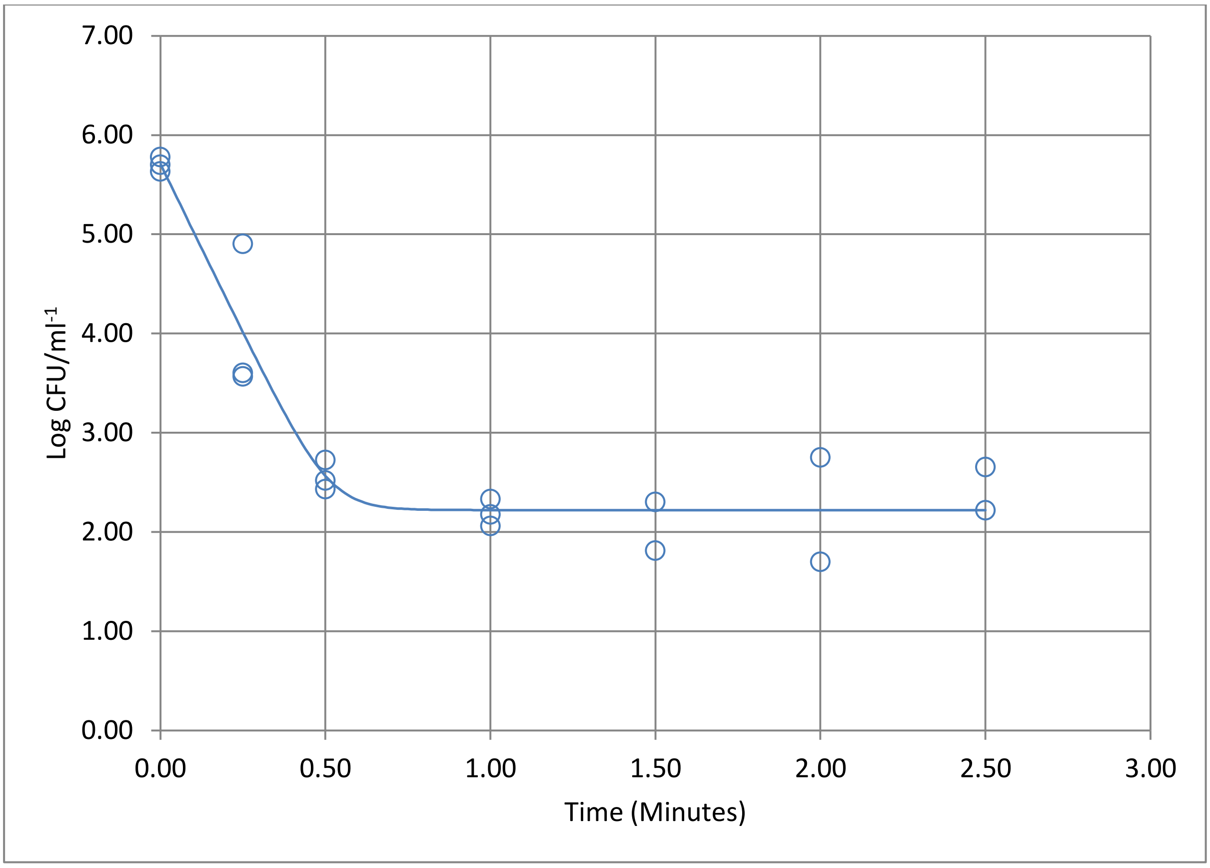

Figure 372. Plot illustrating predicted response curve using a log-linear model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 68°C.

2.3.29 Food-matrices Exterior Time-temperature Simulations: Direct Heating 70°C

Table 359. Assessment of model fit for individual strains following direct heating at 70°C.

Strain	Challenge Type	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	Direct Heat (Un-chilled)	0.762	0.731	0.100
12628 (ST-1773, CC-828)	Direct Heat (Pre-chilled)	0.570	0.738	0.125
12662 ST-257, CC-257	Direct Heat (Un-chilled)	0.582	0.772	0.100
12662 ST-257, CC-257	Direct Heat (Pre-chilled)	0.315	0.921	0.100
13126 (ST-21, CC-21)	Direct Heat (Un-chilled)	0.533	0.893	0.065
13126 (ST-21, CC-21)	Direct Heat (Pre-chilled)	0.585	0.843	0.124
13136 (ST-45, CC-45)	Direct Heat (Un-chilled)	0.331	0.911	0.115
13136 (ST-45, CC-45)	Direct Heat (Pre-chilled)	0.444	0.855	0.075

Table 360. Biphasic model incorporating an asymptotic function for survival of strain 12628 (CC-828) following exposure to direct heat at 70°C.

Parameters	Estimates	Standard Error
F	0.999	0.002
kmax1	22.448	6.533
kmax2	0.511	0.775
N0	5.634	0.440

Table 361. Log-linear model incorporating an asymptotic function for survival of strain 12628 (CC-828) following prior chilling and direct heating at 70°C.

Parameters	Estimates	Standard Error
Kmax	18.524	4.760
Nres	2.910	0.155
N0	5.601	0.329

Table 362. Weibull model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following direct heating at 70°C.

Parameters	Estimates	Standard Error
Nres	2.209	1.415
δ	0.018	0.047
p	0.256	0.198
N0	5.684	0.336

Table 363. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 70°C.

Parameters	Estimates	Standard Error
Kmax	24.512	2.986
Nres	2.652	0.084
N0	5.654	0.182

Table 364. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following direct heating at 70°C.

Parameters	Estimates	Standard Error
Kmax	18.643	3.198
Nres	1.600	0.182
N0	5.465	0.295

Table 365. Log-linear model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 70°C.

Parameters	Estimates	Standard Error
Kmax	21.021	4.436
Nres	2.051	0.174
N0	5.648	0.337

Table 366. Biphasic model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following direct heating at 70°C.

Parameters	Estimates	Standard Error
F	0.998	0.002
kmax1	20.292	3.007
kmax2	0.468	0.288
N0	5.532	0.191

Table 367. Biphasic model incorporating an asymptotic function for survival of strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 70°C.

Parameters	Estimates	Standard Error
F	0.997	0.003
kmax1	31.273	24.254
kmax2	0.636	0.416
N0	5.524	0.256

2.3.30 Food-matrices Exterior Time-temperature Simulations: Direct Heating 70°C

Predicted Response Curves:

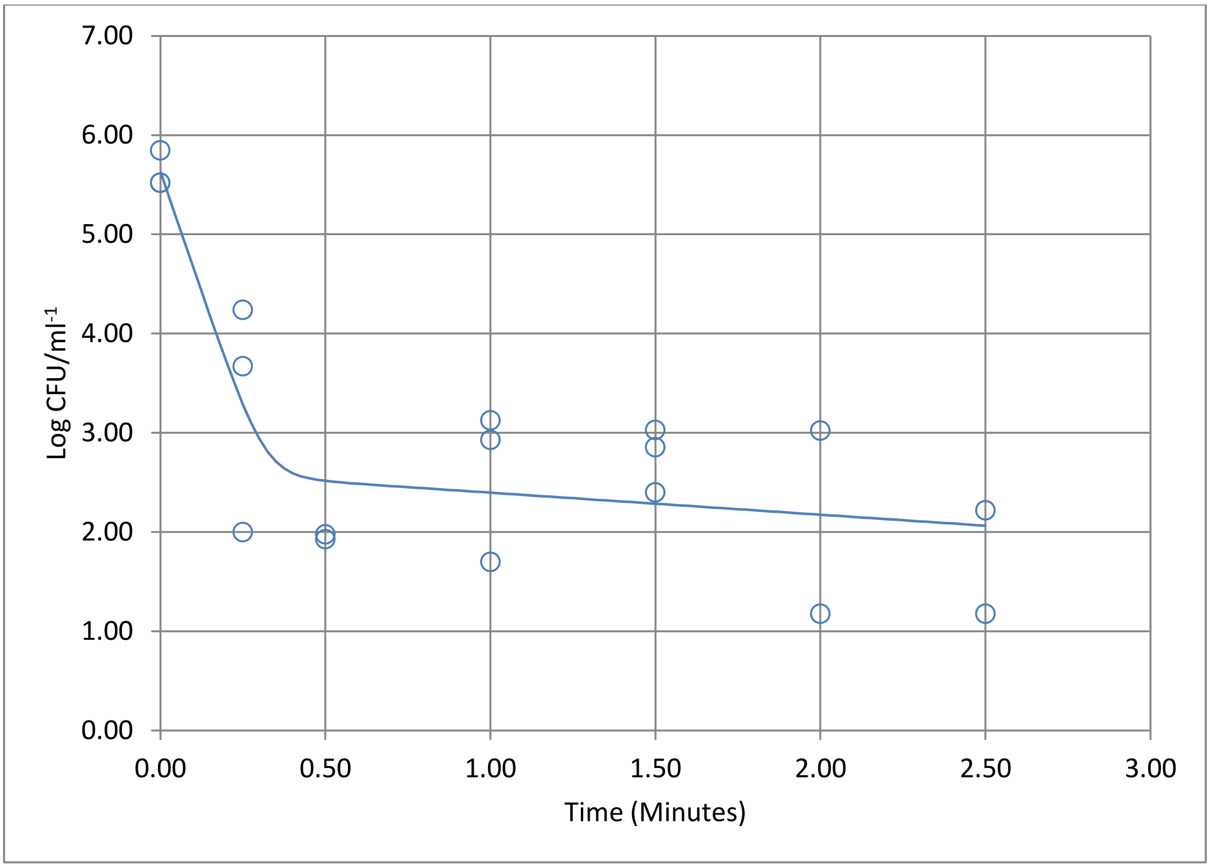

Figure 373. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following direct heating at 70°C.

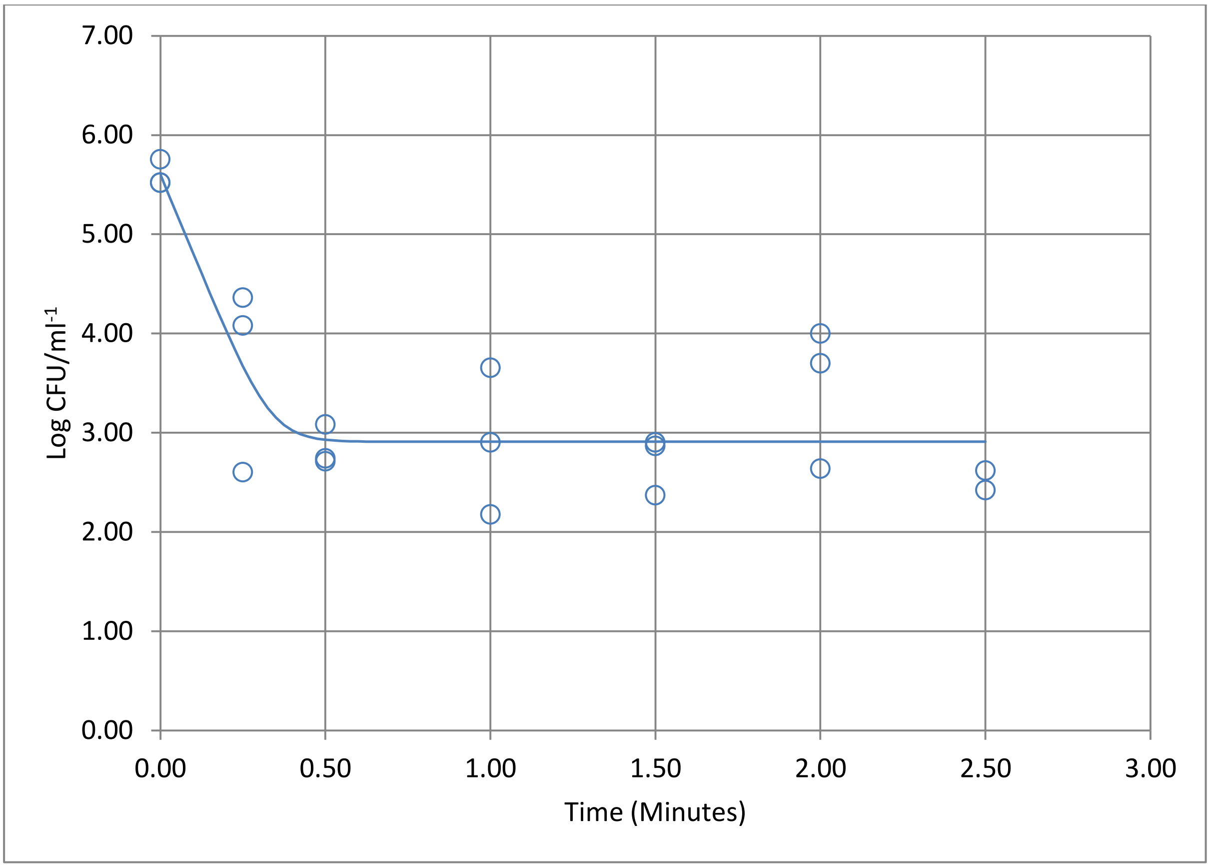

Figure 374. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following prior chilling and direct heating at 70°C.

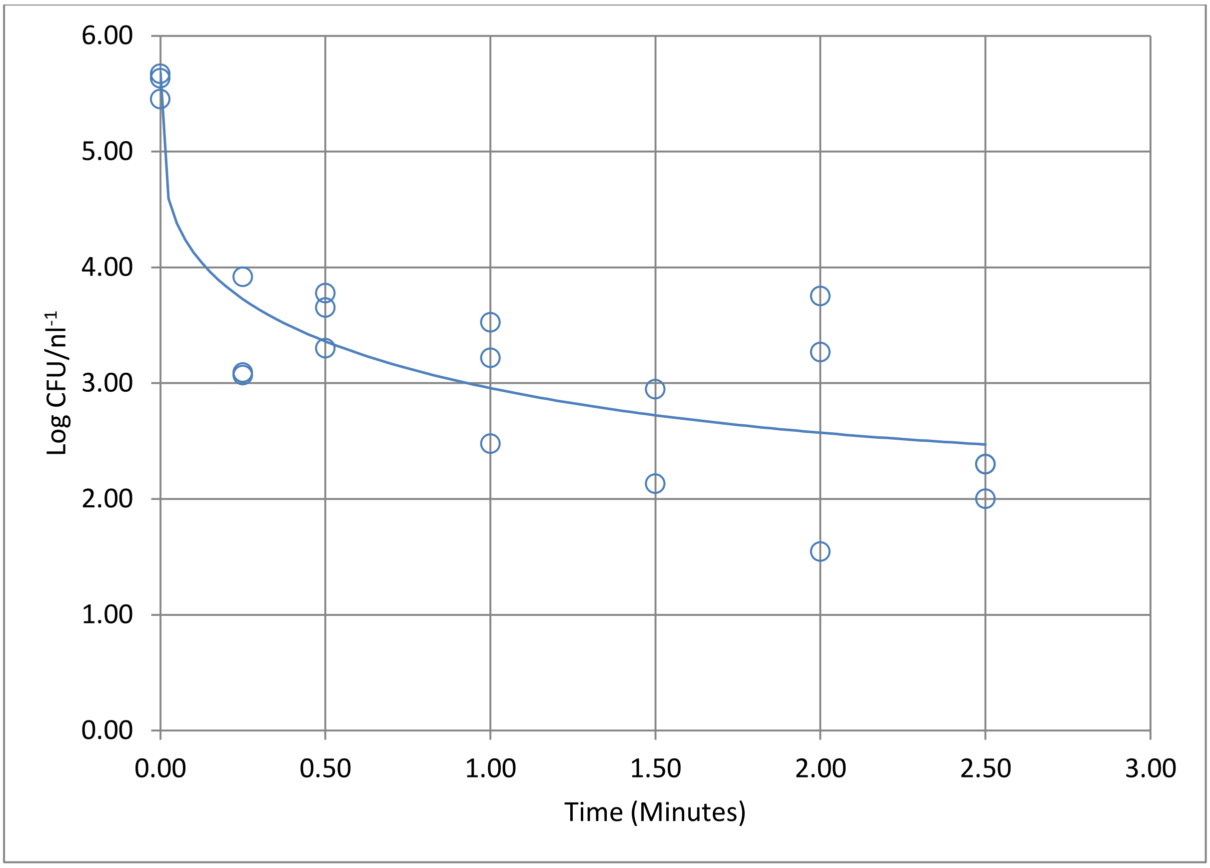

Figure 375. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following direct heating at 70°C.

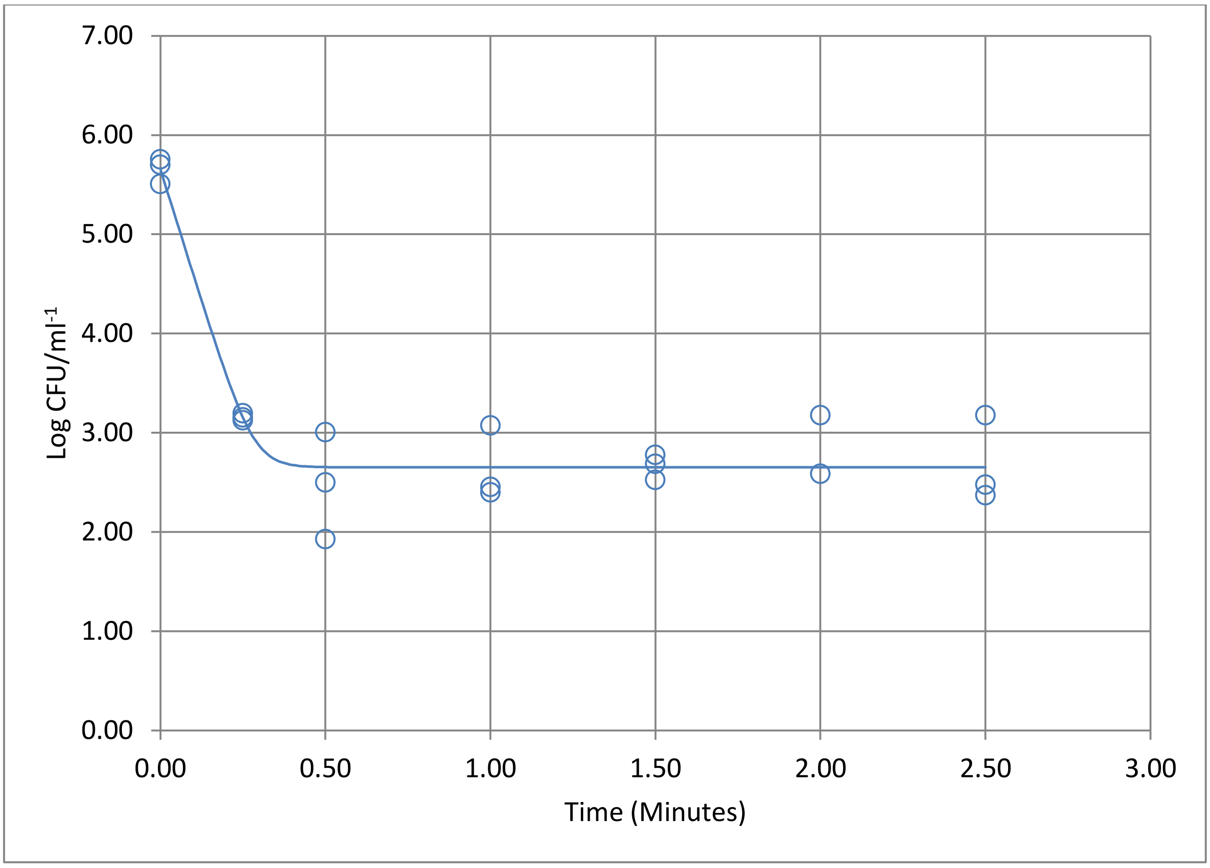

Figure 376. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following prior chilling and direct heating at 70°C.

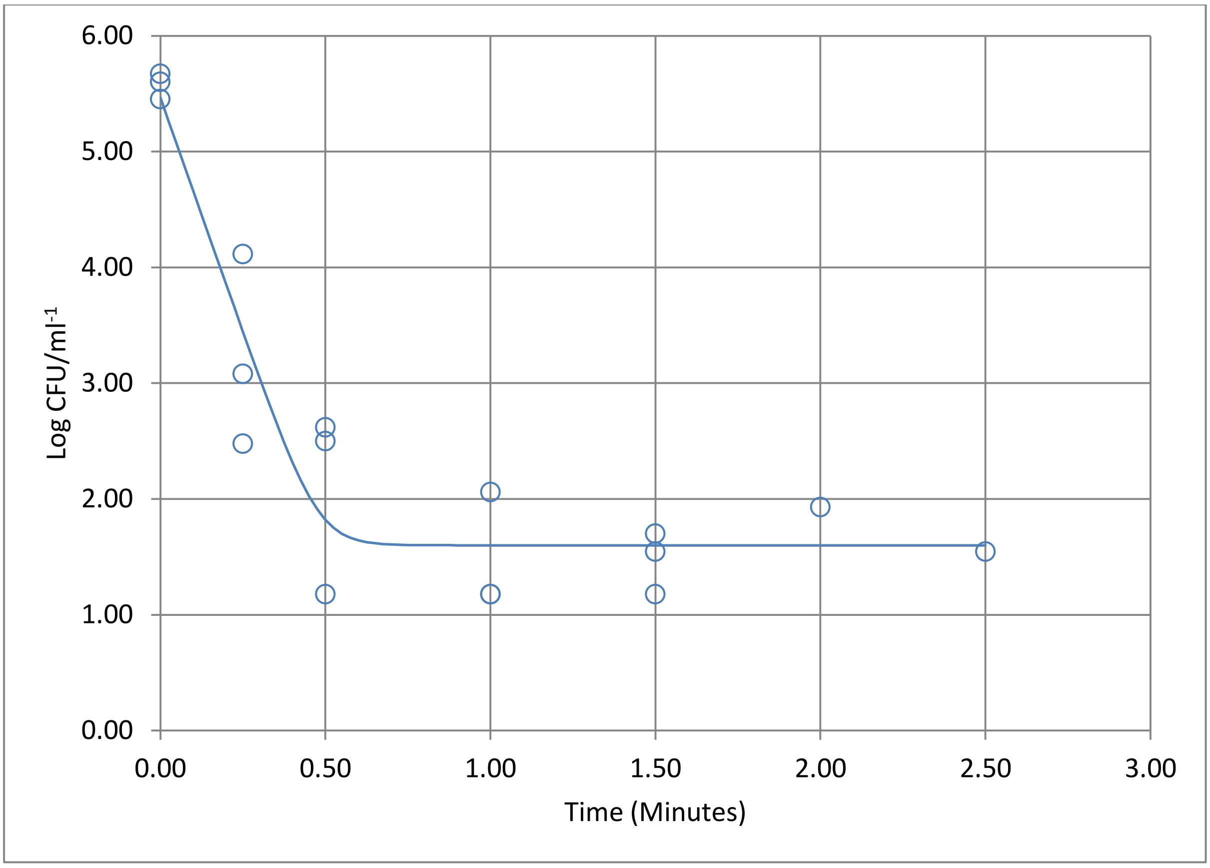

Figure 377. Plot illustrating predicted response curve using a Log-linear model incorporating as asymptotic function for strain 13126 (ST-21, CC-21) following direct heating at 70°C.

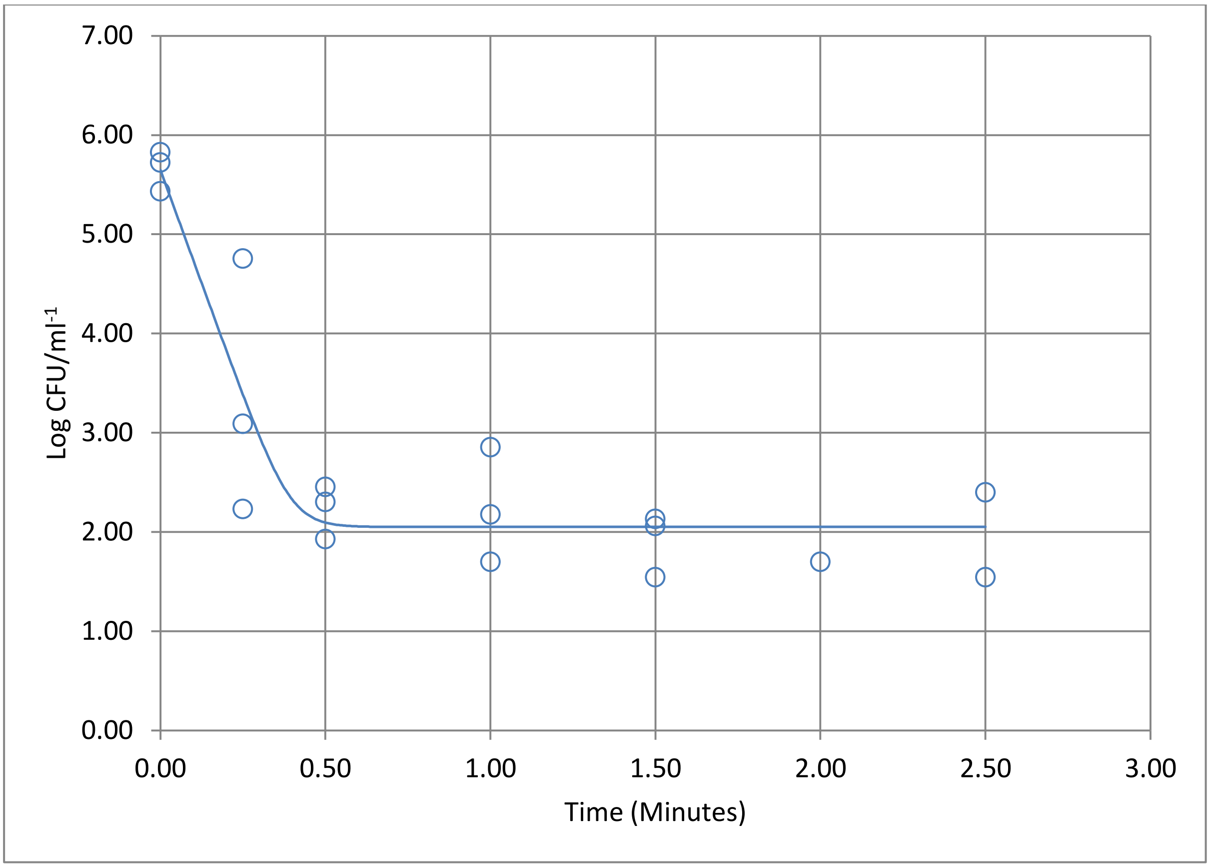

Figure 378. Plot illustrating predicted response curve using a Log-linear model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following prior chilling and direct heating at 70°C.

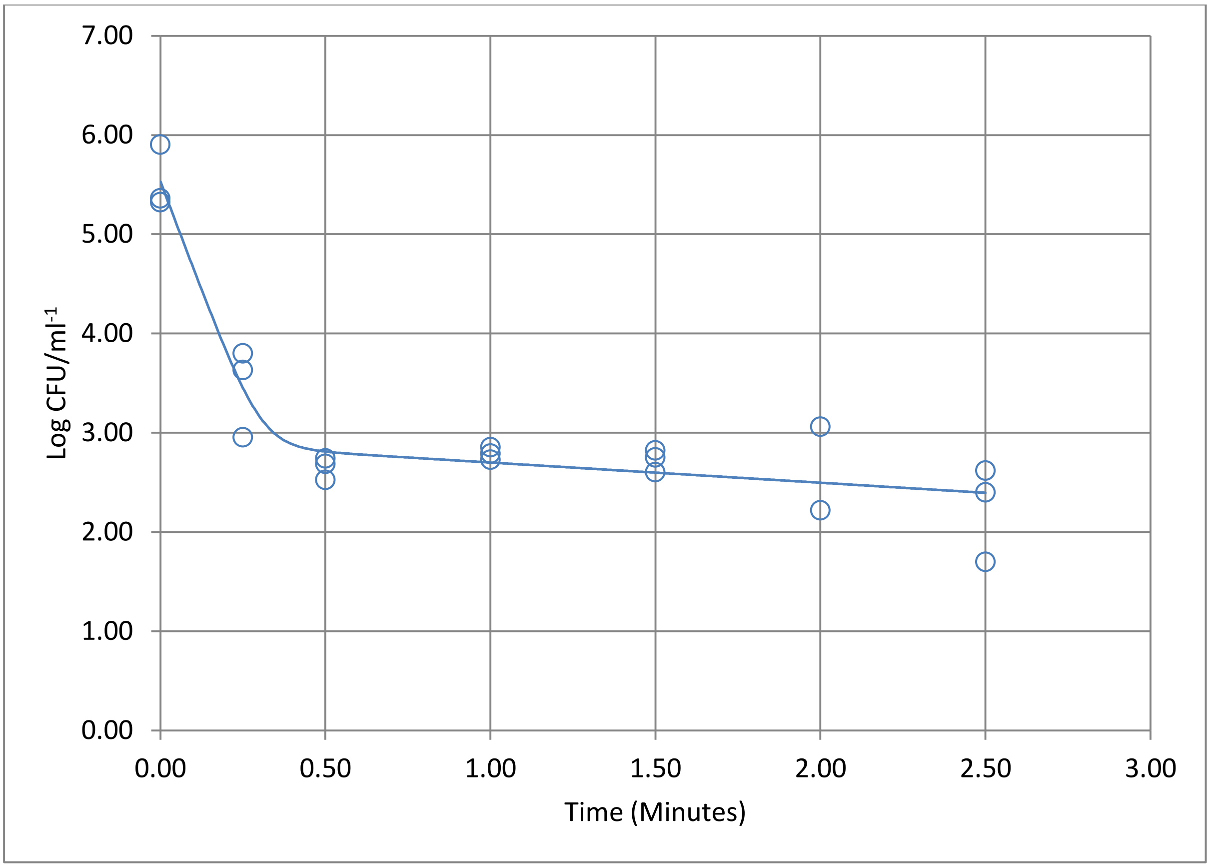

Figure 379. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following direct heating at 70°C.

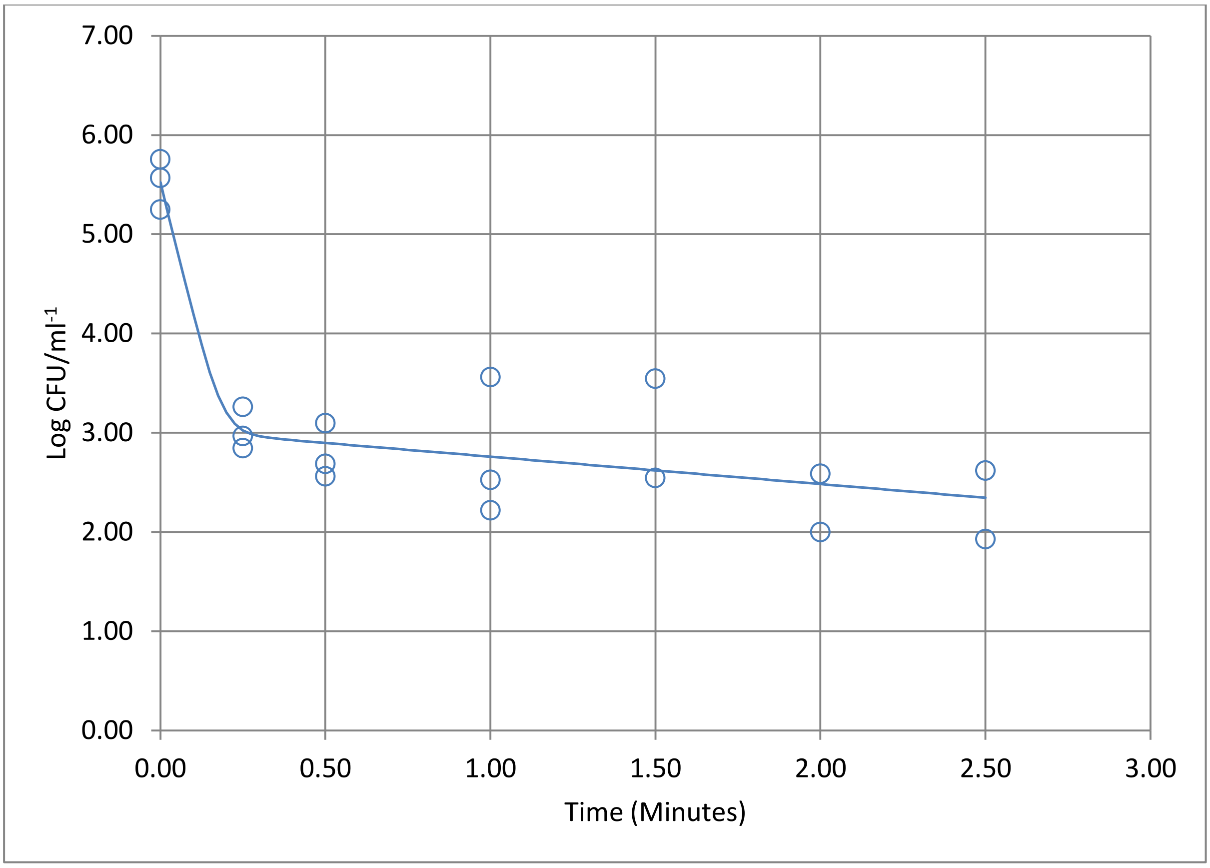

Figure 380. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following prior chilling and direct heating at 70°C.

2.3.31 Food-matrices Interior Time-temperature Simulations: Gradual Heating at 64°C and 68°C

Table 368. Assessment of individual model fit for strains following gradual heating at 64°C and 68°C.

Strain	Temperature	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	64°C	0.463	0.903	8.054
12662 (ST-257, CC-257)	64°C	0.411	0.948	11.260
12628 (ST-1773, CC-828)	68°C	0.240	0.970	7.977
12662 (ST-257, CC-257)	68°C	0.543	0.885	11.126
13126 (ST-21, CC-21)	68°C	0.363	0.920	7.839
13136 (ST-45, CC-45)	68°C	0.467	0.906	4.420

Table 369. Weibull model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following gradual heating of interior at 64°C.

Parameters	Estimates	Standard Error
Nres	2.955	0.216
δ	8.054	3.238
p	1.497	0.813
N0	6.627	0.267

Table 370. Weibull model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following gradual heating of interior at 64°C.

Parameters	Estimates	Standard Error
Nres	2.969	0.168
δ	11.260	1.230
p	3.659	1.030
N0	6.906	0.237

Table 371. Weibull model incorporating an asymptotic function for survival of strain 12628 (ST-1773, CC-828) following gradual heating of interior at 68°C.

Parameters	Estimates	Standard Error
Nres	2.229	0.116
δ	7.977	0.949
p	2.722	0.874
N0	5.703	0.139

Table 372. Weibull model incorporating an asymptotic function for survival of strain 12662 (ST-257, CC-257) following gradual heating of interior at 68°C.

Parameters	**Estimates**	**Standard Error**
Nres	2.896	0.222
δ	11.126	1.107
p	4.508	1.727
N0	6.536	0.313

Table 373. Weibull model incorporating an asymptotic function for survival of strain 13126 (ST-21, CC-21) following gradual heating of interior at 68°C.

Parameters	**Estimates**	**Standard Error**
LOG10(Nres)	2.265	0.188
delta	7.839	1.644
p	2.425	1.289
LOG10(N0)	5.449	0.209

Table 374. Log-linear model for survival of strain 13136 (ST-45, CC-45) following gradual heating of interior at 68°C.

Parameters	**Estimates**	**Standard Error**
kmax	0.522	0.048
LOG10(N0)	5.548	0.258

2.3.32 Food-matrices Interior Time-temperature Simulations: Gradual Heating 64°C and 68°C

Predicted Response Curves:

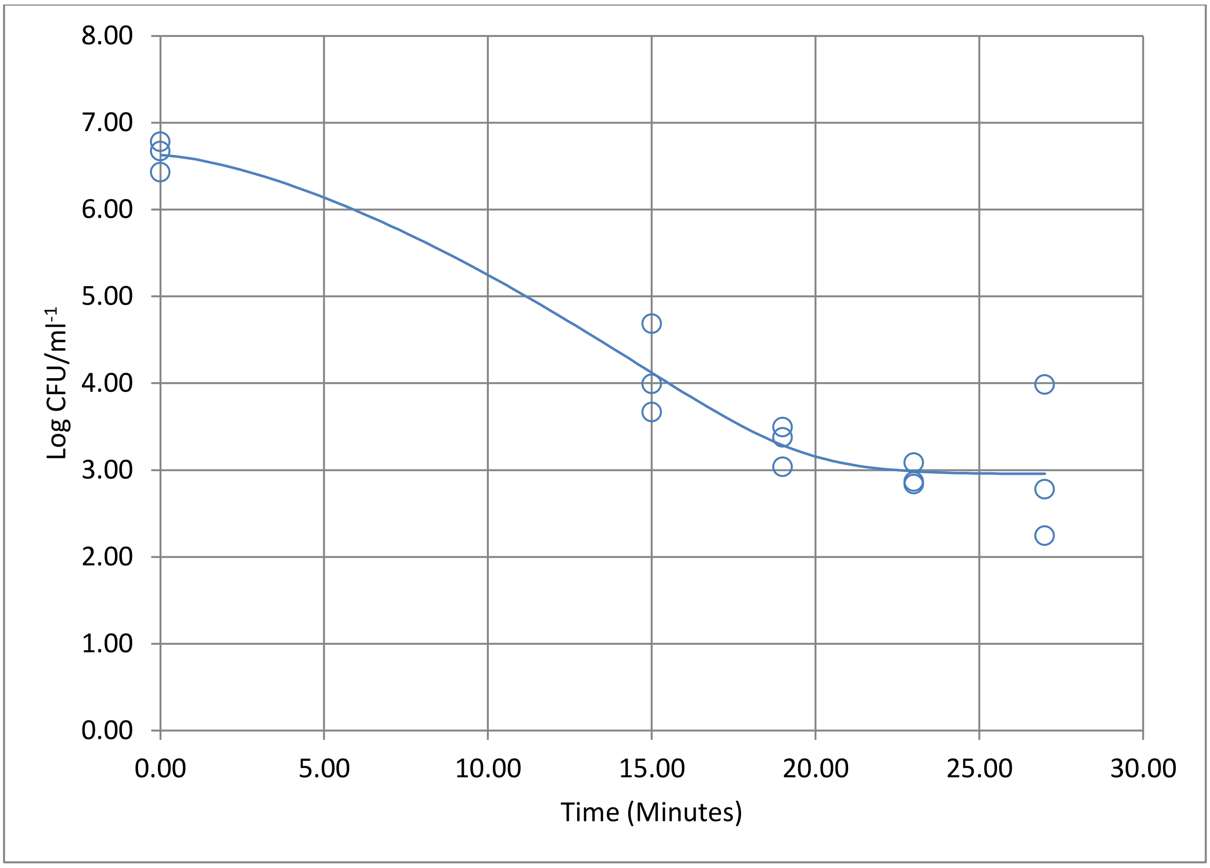

Figure 381. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following gradual heating of interior food matrices at 64°C.

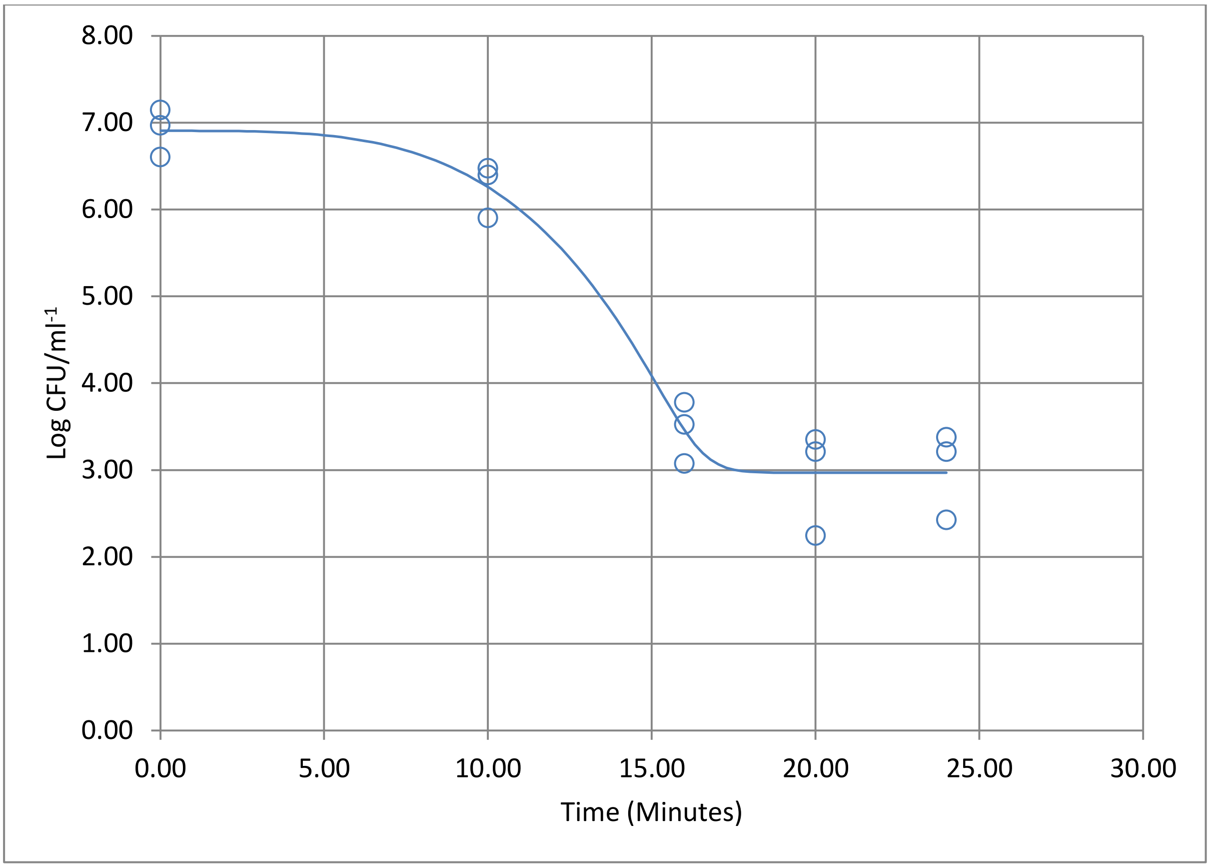

Figure 382. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following gradual heating of interior food matrices at 64°C.

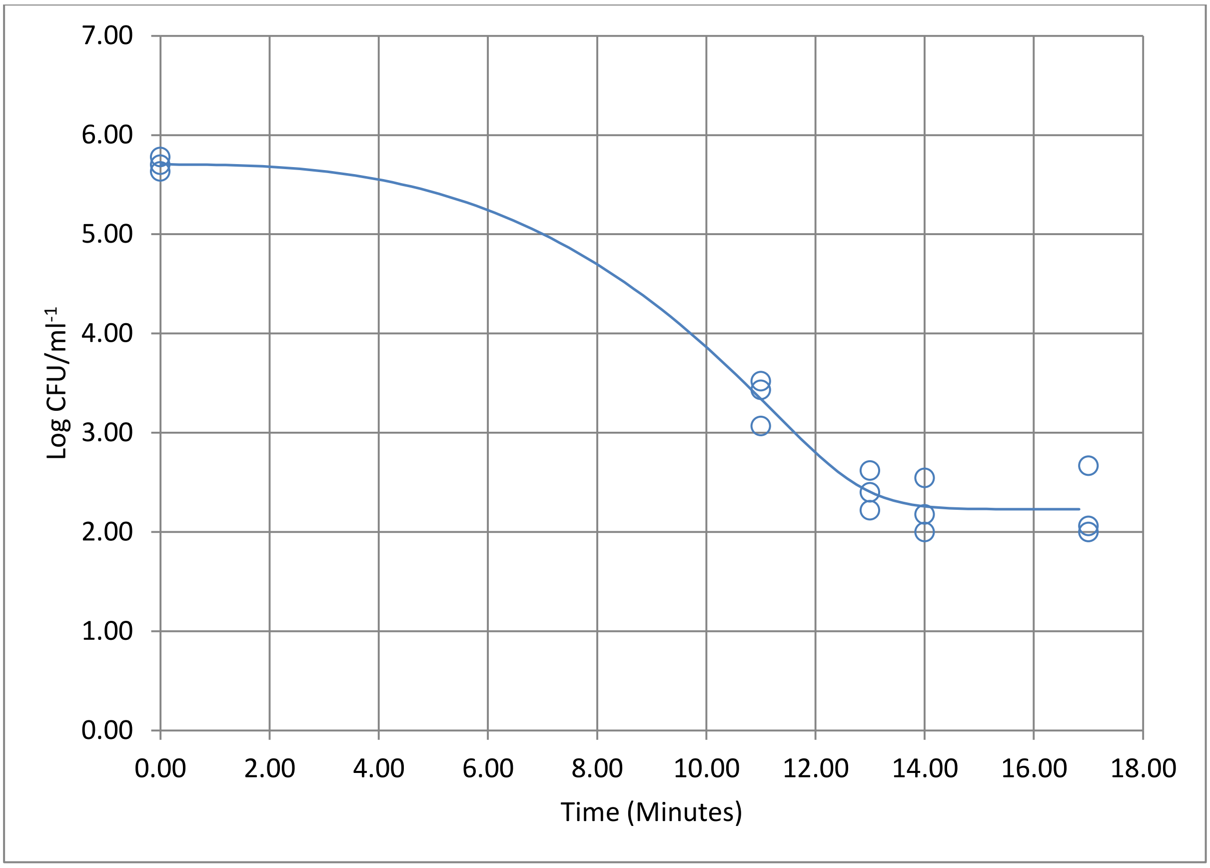

Figure 383. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following gradual heating of interior food matrices at 68°C.

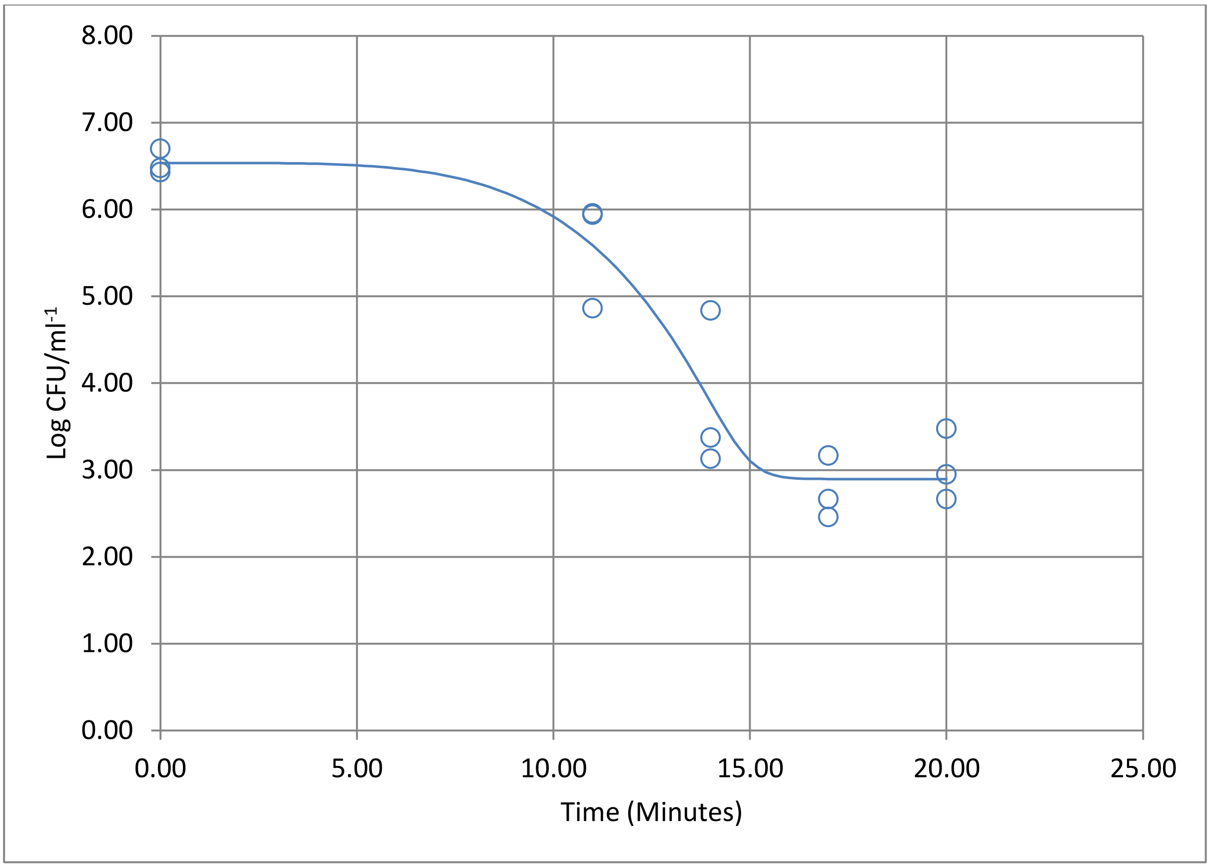

Figure 384. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following gradual heating of interior food matrices at 68°C.

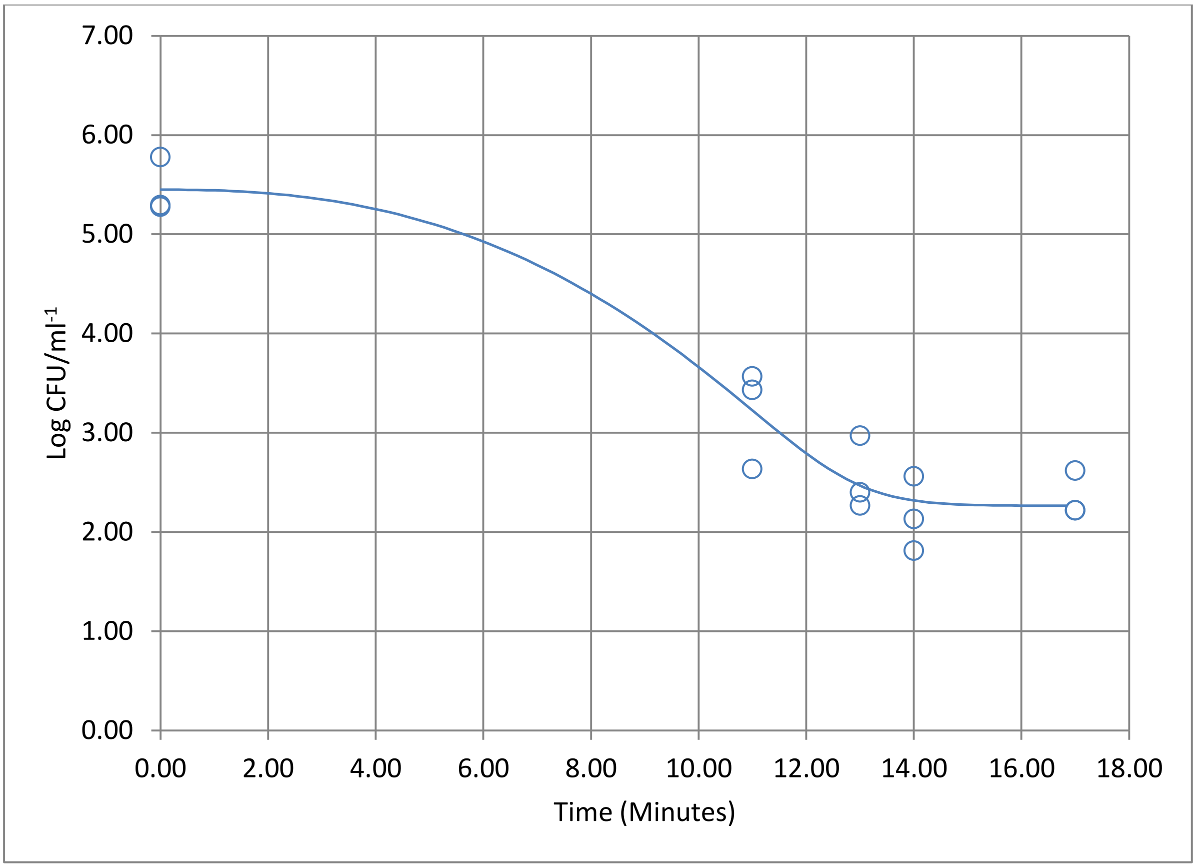

Figure 385. Plot illustrating predicted response curve using a Weibull model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following gradual heating of interior food matrices at 68°C.

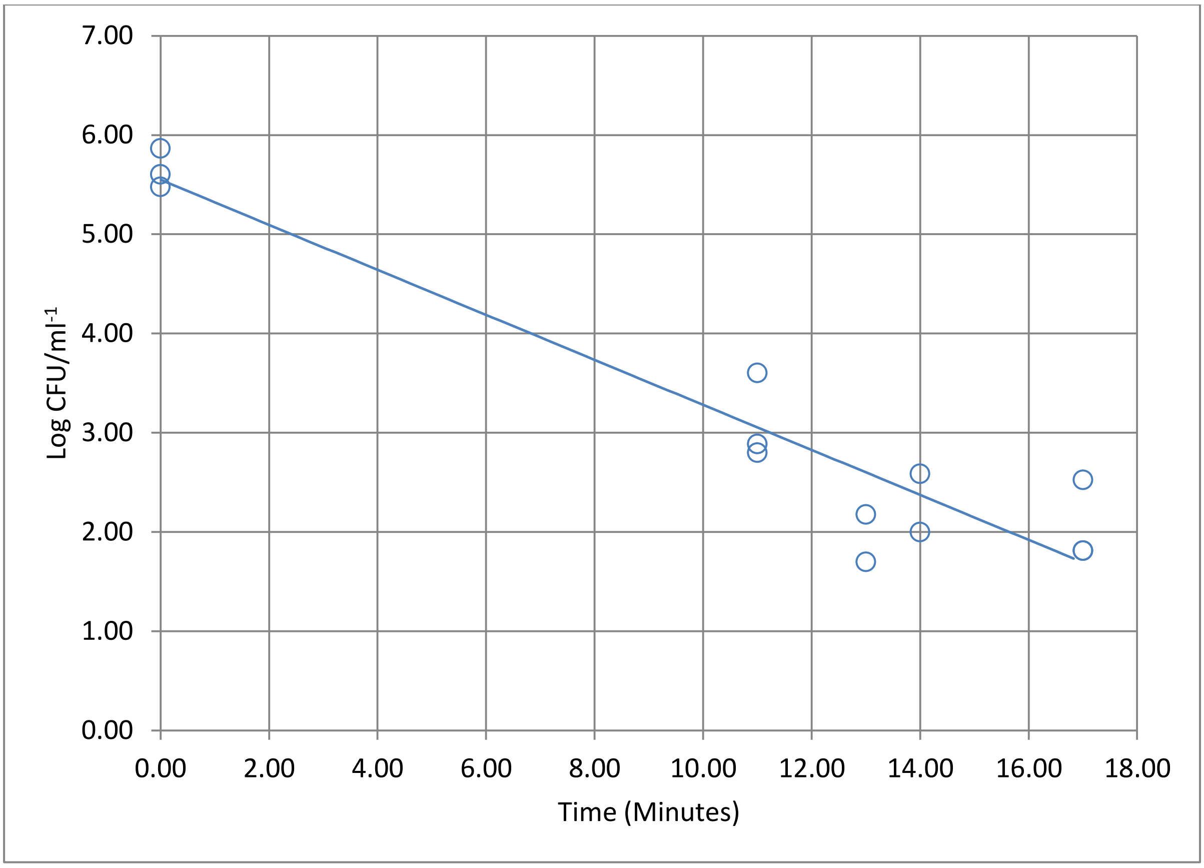

Figure 386. Plot illustrating predicted response curve using a log-linear model for strain 13136 (ST-45, CC-45) following gradual heating of interior food matrices at 68°C.

2.3.33 Food-matrices Interior Time-temperature Simulations: Direct Heating at 64°C and 68°C

Table 375. Assessment of individual model fit for strains following gradual heating at 64°C and 68°C.

Strain	Temperature	RMSE	$R^2_{adjusted}$	D-value
12628 (ST-1773, CC-828)	64°C	0.285	0.947	0.728
12662 (ST-257, CC-257)	64°C	0.481	0.861	0.740
13136 (ST-45, CC-45)	64°C	0.466	0.924	5.280
12628 (ST-1773, CC-828)	68°C	0.594	0.846	0.680
12662 (ST-257, CC-257)	68°C	0.571	0.867	0.490
13126 (ST-21, CC-21)	68°C	0.490	0.892	0.610
13136 (ST-45, CC-45)	68°C	0.500	0.870	0.701

Table 376. Biphasic model for survival of strain 12628 (ST-1773, CC-828) following direct heating of interior at 64°C.

Parameters	Estimates	Standard Error
f	0.999	0.000
kmax1	3.189	0.327
kmax2	0.054	0.033
N0	6.519	0.164

Table 377. Log-linear model incorporating an asymptotic function for survival of strain 12662 (ST-1773, CC-828) following direct heating of interior at 64°C.

Parameters	Estimates	Standard Error
f	1.000	0.000
kmax	3.135	0.521
Nres	3.161	0.134
N0	6.441	0.278

Table 378. Log-linear model for survival of strain 13136 (ST-45, CC-45) following gradual heating of interior at 64°C.

Parameters	Estimates	Standard Error
kmax	0.434	0.037
LOG10(N0)	6.580	0.257

Table 379. Biphasic model for survival of strain 12628 (ST-1773, CC-828) following direct heating of interior at 68^{o}C.

Parameters	Estimates	Standard Error
f	1.000	0.000
kmax1	3.387	0.593
kmax2	0.000	0.136
N0	6.314	0.343

Table 380. Biphasic model for survival of strain 12662 (ST-257, CC-257) following direct heating of interior at 68^{o}C.

Parameters	Estimates	Standard Error
f	1.000	0.000
kmax1	4.694	2.036
kmax2	0.164	0.144
LOG10(N0)	6.457	0.330

Table 381. Biphasic model for survival of strain 13126 (ST-21, CC-21) following direct heating of interior at 68^{o}C.

Parameters	Estimates	Standard Error
f	1.000	0.000
kmax1	3.789	0.597
kmax2	0.072	0.115
LOG10(N0)	6.528	0.283

Table 382. Biphasic model for survival of strain 13136 (ST-45, CC-45) following direct heating of interior at 68^{o}C.

Parameters	Estimates	Standard Error
f	0.998	0.002
kmax1	3.275	0.733
kmax2	0.222	0.117
LOG10(N0)	6.445	0.288

2.3.34 Food-matrices Interior Time-temperature Simulations: Direct Heating 64^{o}C and 68^{o}C

Predicted Response Curves:

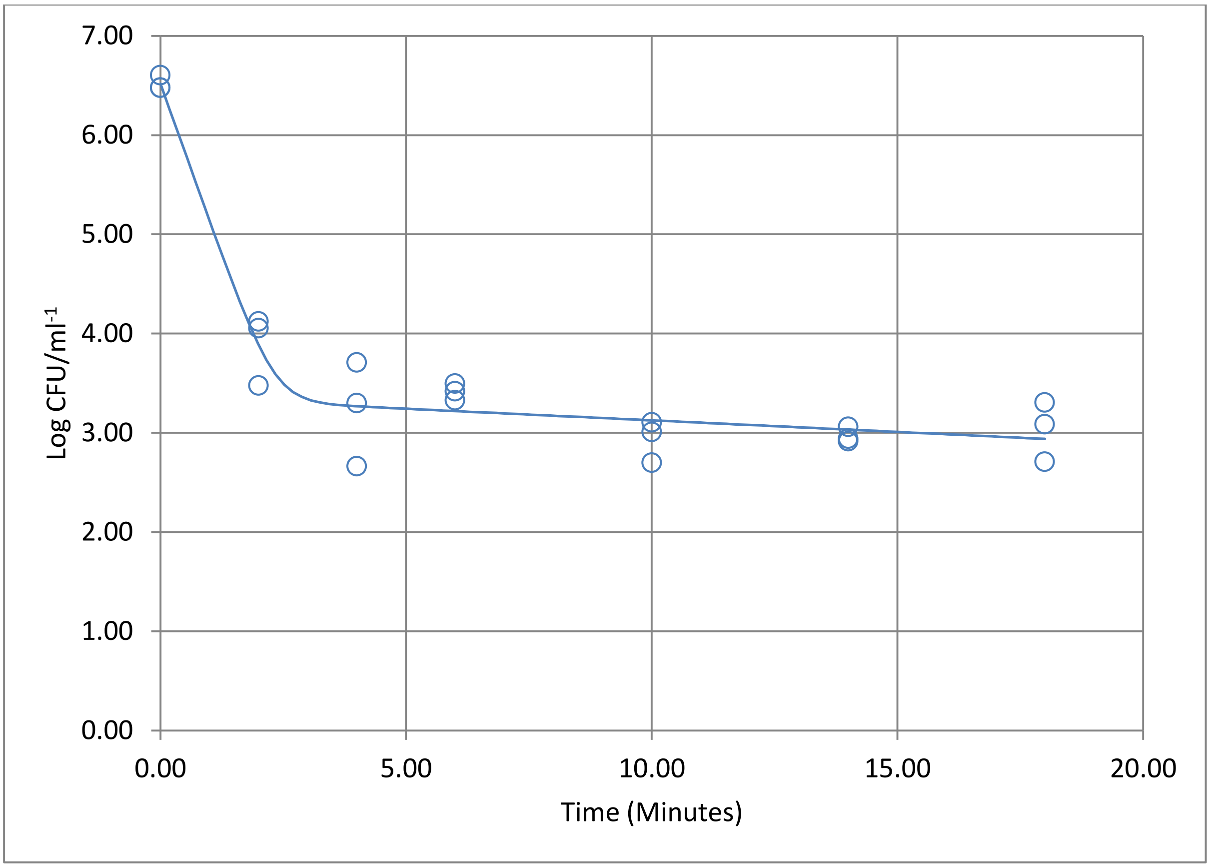

Figure 387. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following extended direct heating of interior food matrices at 64°C.

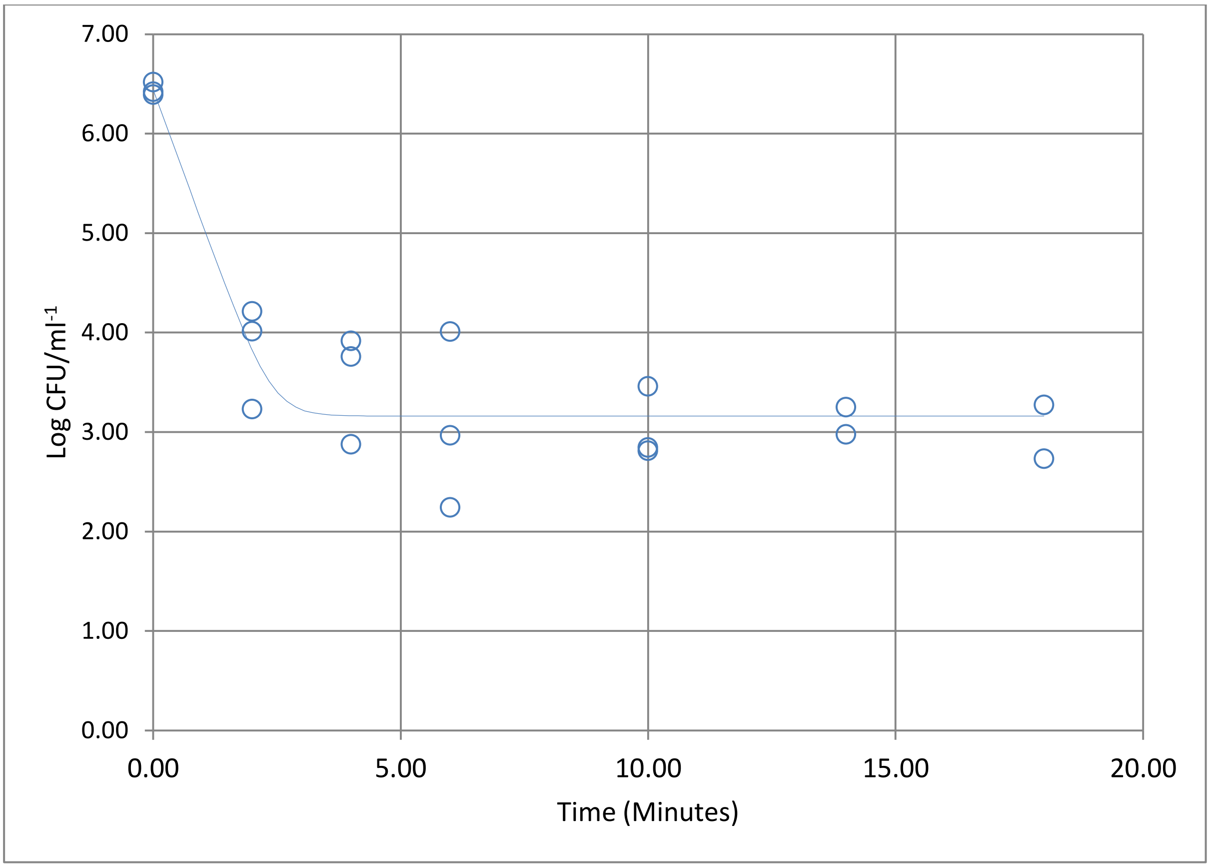

Figure 388. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following extended direct heating of interior food matrices at 64°C.

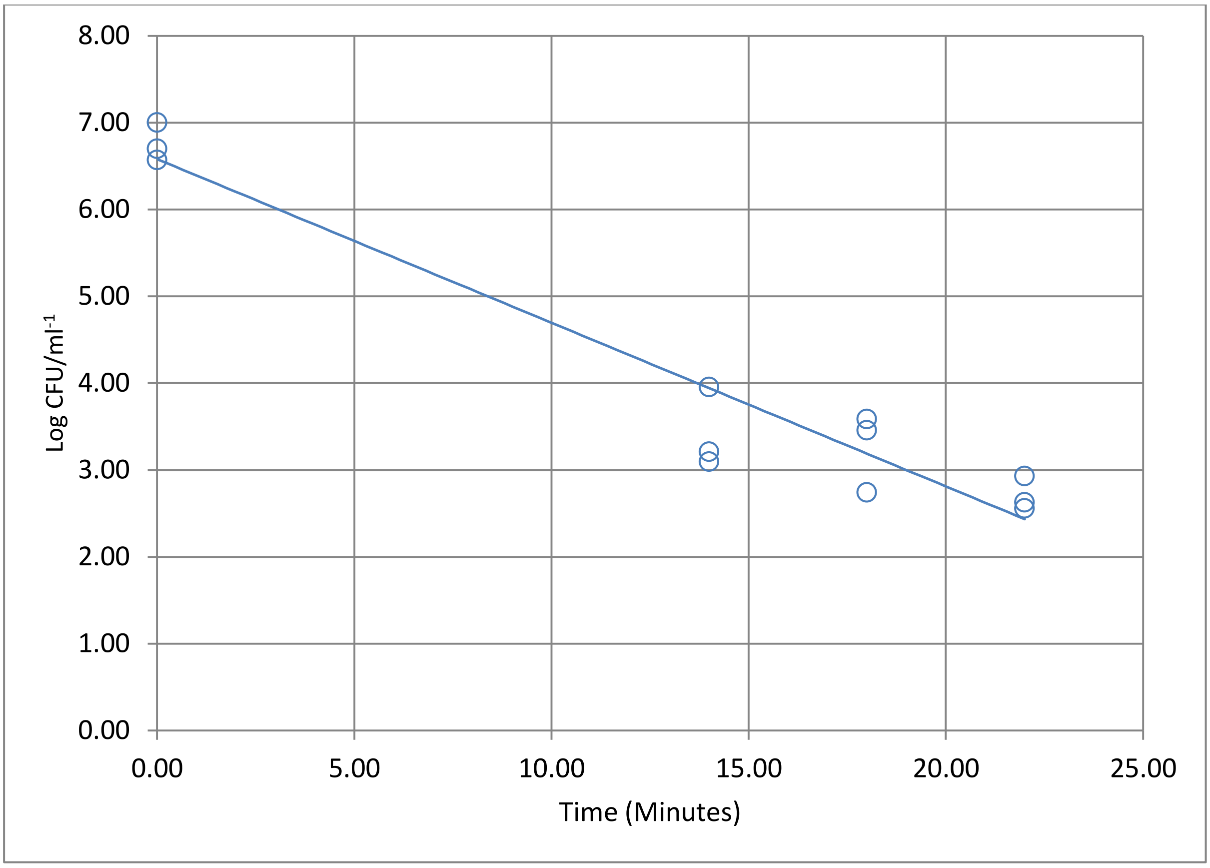

Figure 389. Plot illustrating predicted response curve using a log-linear model for strain 13136 (ST-45, CC-45) following extended direct heating of interior food matrices at 64°C.

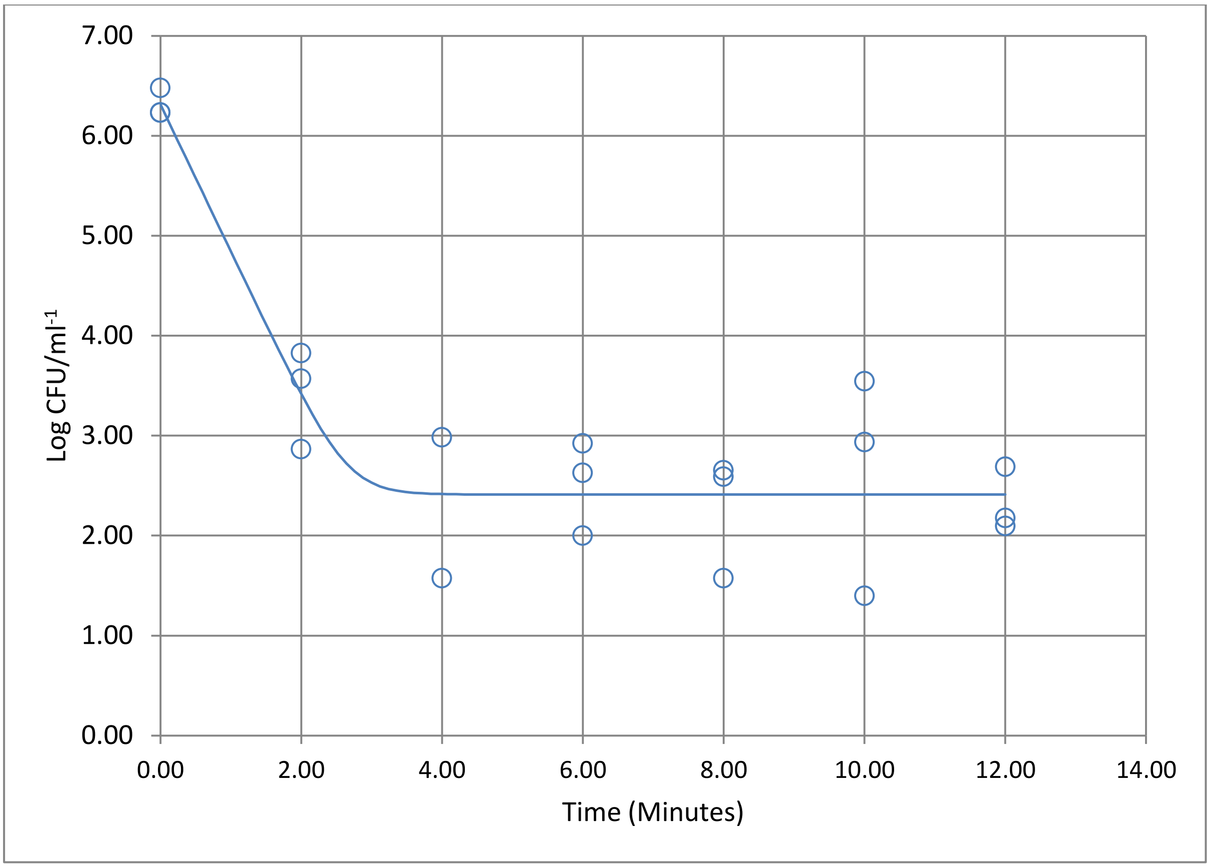

Figure 390. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 12628 (ST-1773, CC-828) following direct heating of interior food matrices at 68°C.

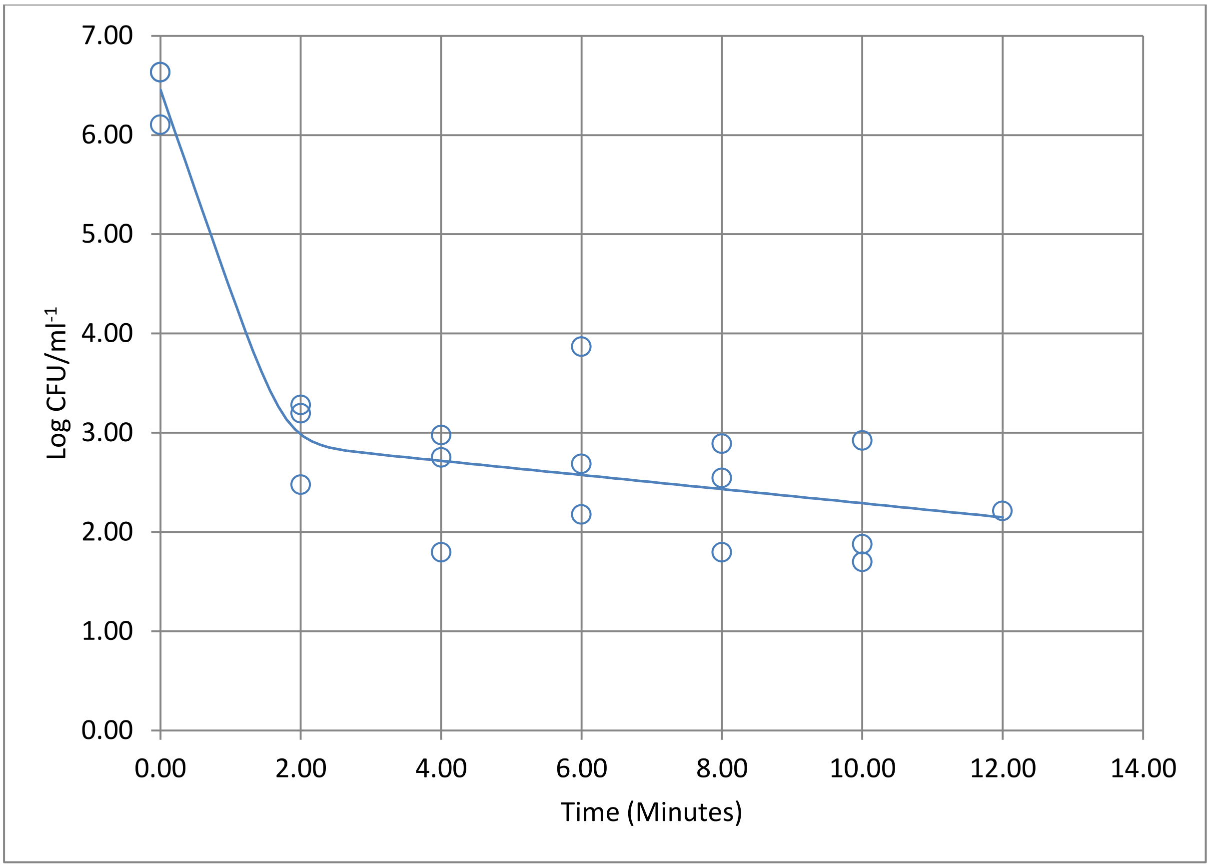

Figure 391. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 12662 (ST-257, CC-257) following direct heating of interior food matrices at 68°C.

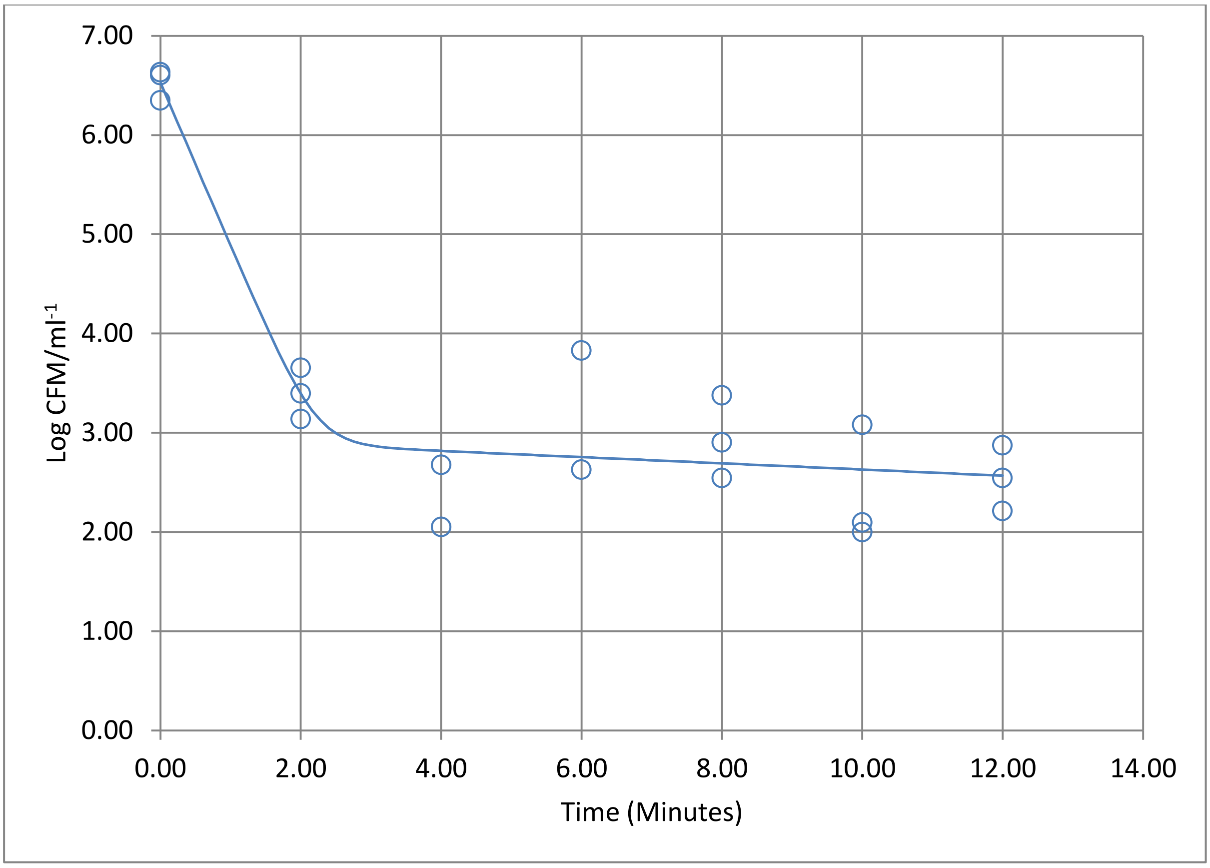

Figure 392. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13126 (ST-21, CC-21) following direct heating of interior food matrices at 68°C.

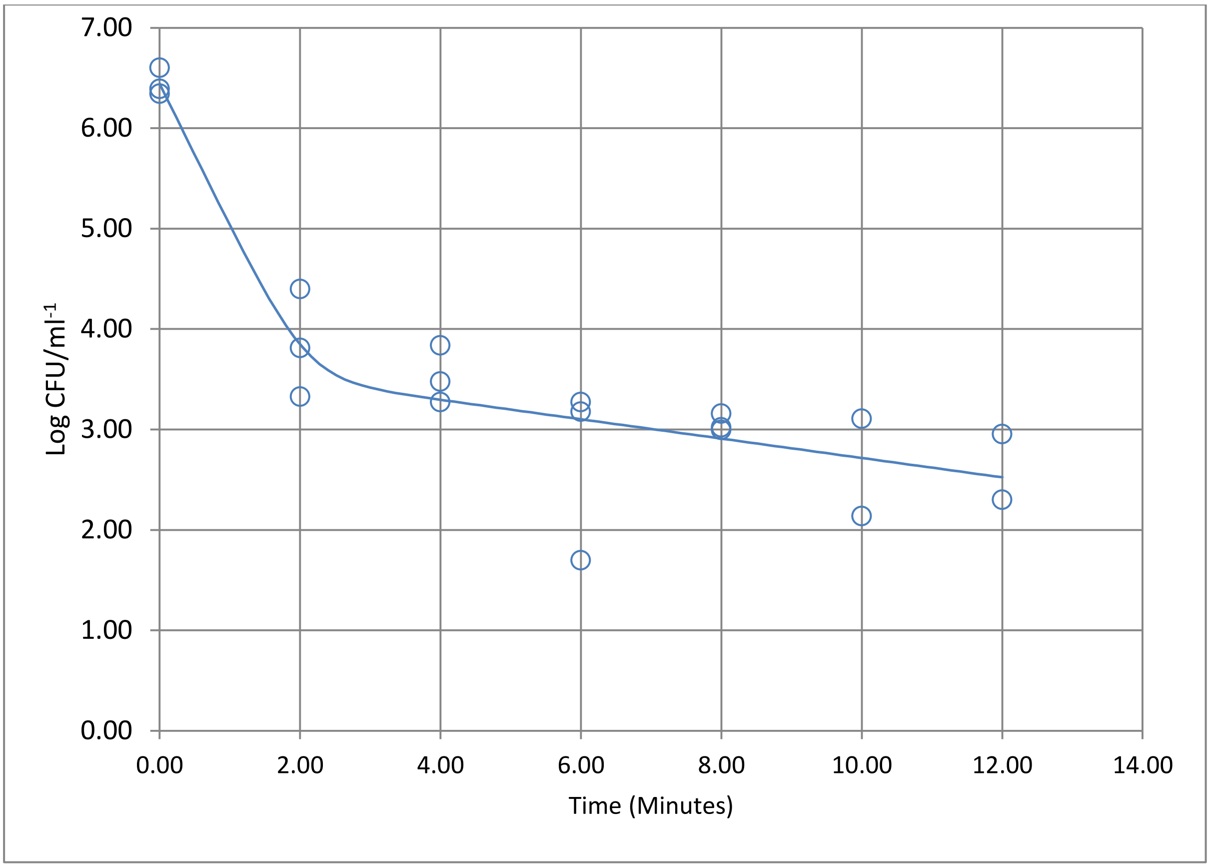

Figure 393. Plot illustrating predicted response curve using a Biphasic model incorporating an asymptotic function for strain 13136 (ST-45, CC-45) following direct heating of interior food matrices at 68°C.

2.4 DISCUSSION

2.4.1 Time-temperature Simulations

The overall fit of models to data varied according to strain and the magnitude of bi-physical stress. This variation may be due to increased levels of experimental heterogeneity encountered during the recovery and observation phase of simulation, where the numbers of cells recovered during is more variable at later sampling points (See Figure 236). In general, the underlying response of strains differed in accordance with exposure to temperature. For instance, models incorporating a shoulder effect and asymptote, or models that generated combined concave response curves were fit to data for simulations undertaken at 56°C.

For simulations undertaken at 60°C, a combination of first-order kinetics models, Weibull and mixed Weibull distribution models were used to generate predicted response curves. In comparison to predicted response curves for simulations at 56°C, the survival of each strain was characterised by a reduced shoulder effect followed by a gradual decline in survival through time. By contrast, biphasic and log-linear first-order kinetics models were used exclusively to generate predicted response curves for time-temperature simulations undertaken at 64°C. These models generated predicted response curves that demonstrate a rapid decrease in survival of an initial subpopulation followed by either a gradual decrease in survival of an additional subpopulation, or asymptote effect indicating an ability to resist biophysical stress at higher temperatures. The overall fit of models generated to describe the survival of strains at 56°C was greater than the fit of models for simulations undertaken at 60°C and 64°C. Similarly, survival of strains appeared to decline from simulations undertaken at 60°C in comparison to those at 64°C.

This evaluation is supported by comparing the time to first decimal reduction (D-value) for each time-temperature simulation. We used a Generalized Least Squares (GLS) approach to assess differences in the time taken to achieve a one-log reduction in the counts of cells. There was a significant difference between in D-value between Simulations undertaken at 56°C and those undertaken at 60°C and 64°C, indicating that initial resistance to bio-physical stress declined accordance with an increase in temperature.

2.4.2 pH and Time-temperature Simulations

The fit of models to data generated by combined pH and time-temperature simulations data varied according to strain and the magnitude of the bi-physical and bio-chemical challenge. Comparatively, overall model fit was greater for predicted response curves generated form combined pH and time-temperature simulations following exposure to heating at 56°C. Model fit subsequently declined for combined pH and time-temperature simulations undertaken at 60°C and 64°C. The decrease in model fit may be due to increased experimental heterogeneity and may be particularly relevant for simulations undertaken at 64°C. There was broad similarity in types of models used to generate predicted response curves for combined pH and temperature simulations undertaken at 56°C. The first-order kinetic biphasic model was used to generate predicted response curves for all strains at pH 4.5. The underlying response of strains at pH 5.5 – pH 8.5 were similar insofar as predicted response curves were generated using broad class of Weibull models, namely Weibull model, Weibull model incorporating asymptotic function and the mixed Weibull distribution model. In the first instance, predicted response curves generated using the biphasic model indicate that *Campylobacter* strains are susceptible to bio-chemical stress. In contrast, the class Weibull models, and the mixed Weibull model in particular, was used to generate single or double concave predicted response curves for simulations undertaken at pH 5.5 – pH 8.5. This may suggest that initial subpopulations within strains may exhibit enhanced capacity to resist biochemical stress.

The biphasic and log-linear first-order kinetics models were predominantly used to generate predicted response curves for survival of strains at pH 4.5 and pH 8.5 following heating at 60°C, indicating that strains were susceptible to combined and multiplicative effects of increased bio-physical and bio-chemical stress. By contrast, the mixed Weibull distribution model was used predominantly used to generate predicted response curves for simulations undertaken between pH 5.5 – pH7.5. However, two exceptions were noted; the Weibull model was used to generated predicted response curves for strain 13136 (ST-45, CC-45) for simulations undertaken at pH 4.5 and pH 8.5, whereas the mixed Weibull model was used throughout all combined pH simulations for strain 13126 (ST-21, C-21).

The classes of models used to generate predictive response curves for combined simulations undertaken at 64°C varied according to pH and strain. Variants of the Weibull class of models were used in conjunctions with first-order kinetics models to generate both concave and convex predicted response curves. Concave response curves were typically generated for simulations at pH 4.5 and pH 8.5, whereas convex response curves were generated for survival of strains at pH 5.5 – pH 7.5. A general pattern emerged throughout this particular phase of the study whereby variants of the class of Weibull models were used to generate convex survival curves for simulations at pH 5.5 and pH 6.5 and in some instances, pH 7.5. The presence of a lag, or shoulder effect indicated that these acidic conditions may be optimal for the survival of *Campylobacter.* This evaluation was supported when we examined the time to first decimal reduction for each combined pH and time-temperature simulation.

We used Generalized Least Squares to examine potential differences between estimated D-values for each combined pH and temperature simulation. In general, results indicate that estimated D-values, and therefore resistance to stress, decline following combined exposure to acidic stress and high temperature. Average estimated D-values at 56^{o}C were significantly higher in comparison to those estimated at 60^{o}C and 64^{o}C. Estimated D-values at 56^{o}C were also significantly higher at pH 5.5 – pH 8.5 when compared to pH 4.5. Significant reductions in estimated D-values were also observed between each individual pH and time-temperature simulation. For instance, the D-value estimated at 60^{o}C for pH 5.5 was significantly lower than the corresponding value estimated at 56^{o}C for pH 5.5. The pattern of significant reductions in estimated D-values was observed for pH 5.5 – pH 8.5 for simulations undertaken at 60^{o}C and for all pH simulations undertaken at 64^{o}C.

However, there was also variation in estimated D-values within each combined pH and time-temperature simulation. The time to first log reduction in counts of cells is highest at 56^{o}C for pH 5.5 – pH 6.5. There was also marked differences in estimated D-values within each temperature group where higher values were estimated for pH 5.5 – pH7.5. This finding is indicative of an enhanced capability to resist acidic stress.

2.4.3.1 Food-matrices Exterior Time-temperature Simulations

For gradual heating simulations undertaken at 56^{o}C strains demonstrated similar survival convex curves with evidence of a tailing-effect at later observation points. The first-order-kinetics log-linear model incorporating a shoulder effect, the Weibull model and the mixed Weibull distribution model were all used to generate concave predicted response curves. In contrast, the Weibull and mixed Weibull distribution models were used exclusively to generate convex predicted response curves for gradual heating simulations undertaken at 70^{o}C.

An assessment of goodness-of-fit indices suggests that the fit of models to data from gradual hating experiments was largely dependent on strain and the temperature used during simulations. Model fit was generally good for simulations undertaken at 56^{o}C. In comparison, overall fit declined during gradual heating simulations undertaken at 70^{o}C and may be due to considerable heterogeneity in observed counts of cells. There was insufficient data to generate models to examine the effects of pre-chilling of food-matrices prior to heating. The log-linear first order kinetics model, incorporating an asymptote function, and the mixed Weibull distribution model were used to generate predicted response curves for direct heating simulations of chilled and un-chilled meat at 56^{o}C. Predicted response curves for these simulations were primarily concave with elongated tails, indicating that strains were able to persist on tissue surfaces for an extended period of time. There was no appreciable difference in overall model fit between chilled and un-chilled simulations.

Models used to generate predicted response curves for remaining direct heating simulations undertaken at 60^{o}C, 64^{o}C, 68^{o}C and 70^{o}C all demonstrated a similar response to those described at 56^{o}C. Biphasic and log-linear first order kinetics models and the Weibull model incorporating an asymptotic function were used to generate predicted response curves, whereby individual strains demonstrated an initial susceptibility to increased temperature followed by a period of enhanced resistance demonstrated by the tailing effect.

An evaluation of the estimated D-values for direct heating simulations indicates that the time to first log-reduction in numbers of cells significantly declines as temperature increases. We did not find a significant difference in the estimated D-value relating to pre-treatment effects of chilled and un-chilled tissue. The Weibull models and first-order kinetic biphasic and log-linear models used to generate predicted response curves reflect differences in the resistance of *Campylobacter* strains within food-matrices. In general, the Weibull models fit to these data describe convex survival curves that demonstrate a reduction in survival towards zero. Conversely, first-order kinetic models data generate predicted response curves with an initial log-linear decrease in survival followed by a noticeable tailing effect that remains continuous through a significant proportion of the experimental simulation. For instance, the predictive models used to generate survival curves for food-matrices simulations undertaken at 56^{o}C demonstrated an elongated tailing effect from 2:00 – 10:00 minutes (see Figure 343) indicating enhanced survival characteristics and resistance to stress at lower temperature. The magnitude of the resistance to stress for strain 12662 (ST-257, CC-257) was described by tailing effect at 60^{o}C was 1:00 – 4:00 minutes (see Figure 356). A similar degree of resistance was observed for simulations undertaken at 64^{o}C where evidence of increased resistance was observed within strains from 0:50 – 4:00 minutes, for example strain 12662 (ST-257, CC-257) (Figure 362). For simulations undertaken at 68^{o}C enhanced resistance was observed for strain 12662 (ST-257, CC-257) from 0:50 – 2:50 minutes (Figure 368). However, it is important to remember that the length of the tailing effects also reflects the respective reduction in the duration of the observation periods for each increase in temperature. Nevertheless, such inherent resistance to heat may have implications for food-processing industry and the control and management of *Campylobacter* in the food chain.

2.4.3.2 Food-matrices Interior Time-temperature Simulations

The survival of *Campylobacter* within food-matrix interiors following gradual heating simulations undertaken using at 64°C and 68°C were primarily analysed using Weibull models incorporating an asymptotic function. The predicted response curves were convex in shape with evidence of tailing effect in excess of 20 minutes. This indicates *Campylobacter* can survive for extended periods of time within food tissue. The underlying survival response curves for strains following direct heating simulations undertaken using at 64°C and 68°C were evaluated using biphasic and log-linear first-order kinetics models incorporating an asymptotic function. The predicted response curves were concave in shape and show an initial and rapid decline in survival before demonstrating an elongated tailing effect indicative of enhanced survival between 5.00 – 20.00 minutes for direct heating simulations undertaken at 64°C and between 4.00 – 12.00 minutes for direct heating simulations undertaken at 68°C. By contrast, the first-order log-linear model was used to describe the response of strain 13136 (ST-45, CC-45). The predicted response curves generated by this model infer a linear decline in survival through time. Attempts to generate a predicted response curve for this strain using other types of models failed. However, this does not imply that the mechanistic response for this particular combination of strain and time-temperature simulation is purely linear. In actuality, the log-linear response may be an artefact of insufficient observations between the initial counts obtained at 0 minutes and the subsequent counts obtained at 11 minutes, rather than an accurate reflection of the underlying mechanism of the strain in response to heating. Complications are also faced in the interpretation of the time until first log-reduction. Estimated D-values for direct heating simulation at 64oC ranged from 0.728 – 5.280. The later value was estimated for strain 13136. It is likely that this estimate may also be a consequence of the model used rather than a reflection of the underlying process. On reflection, an increase in the frequency of observations during this type of experimental simulation would improve model selection and determining the response of strains to bio-physical and bio-chemical challenge.