temperature range for emetic toxin production in rice culture is 25–30°C (Melling and Capel, 1978).

The emetic toxin is heat stable and can withstand normal cooking procedures. Data are few, but the toxin has been reported to be thermostable at 126°C for 90 min (Turnbull *et al.*, 1979). In contrast, the diarrhoeal toxin is heat sensitive, and is inactivated by treatment at 56°C for 5 min.

Control

Foods are commonly contaminated with *B. cereus* owing to the organism's widespread distribution in the environment. Their presence in small numbers (a few hundred cells per gram) is usually not a problem since ingestion of these low populations will not cause illness. Prevention of illness therefore requires the control of spore germination and the prevention of growth of vegetative cells in cooked, ready-to-eat foods.

Properly cooked foods, eaten hot soon after cooking, are safe. Most cooking procedures, including steaming under pressure, frying, grilling and roasting, will generally kill vegetative cells and, probably, spores. Cooking at temperatures of 100°C or below will allow the survival of some spores. Spore germination can be reduced greatly by low temperature, pH or a_w. The emetic toxin is not destroyed by cooking.

Cell multiplication during inadequate cooling of cooked cereal-based or protein-containing foods is a major concern. Conditions that favour *B. cereus* growth in foods include cooking procedures that activate spores followed by slow cooling and storage of large amounts of foods at temperatures between 10° and 50°C. Food to be stored should be cooled rapidly to a temperature that prevents the growth of *B. cereus*. Food to be held in a warm state should be maintained above 60°C.

Table A Taxonomic position of *Bacillus cereus* (aerobic, facultatively anaerobic, rod-shaped spore-formers, catalase-positive)

Group I	Group II	Group III
Sporangia not swollen by spore Small-celled bacilli, <0.9 μm cell diameter, non-vacuolated on glucose–nutrient agar	Sporangia swollen, oval spores Large-celled bacilli, >0.9 μm cell diameter, vacuolated on glucose–nutrient agar	Sporangia swollen, round spores.
• *B. subtilis* • *B. licheniformis* • *B. pumilus* • *B. coagulans* • *B. firmus* • *B. lentus*	Strictly aerobic: • *B. megaterium*	Facultatively anaerobic: • *B. cereus* • *B. anthracis* • *B. thuringiensis* • *B. mycoides* Rhizoid growth: • *B. mycoides* Parasporal crystal: • *B. thuringiensis* Non-motile: • *B. anthracis* Motile: • *B. cereus*

Table B Limits for growth

	Minimum	Optimum	Maximum
Temperature (°C)	4	30–40	55
pH	5.0	6.0–7.0	8.8
Water activity	0.93	–	–

Growth limits for organisms under ideal conditions

Table 1a Temperature 1–55°C†

Substrate	Temp. (°C)	Growth (h/gen)	Growth (log/d)	Growth (descriptive)	pH	No. of strains	Ref.
10% tryptose[a,b]	30	0.31	–	–	7.0	1	1
2% soy flour[a,b]	30	0.31	–	–	7.0	1	1
2% peanut flour[a,b]	30	0.34	–	–	7.0	1	1
5% field pea flour[a,b]	30	0.32	–	–	7.0	1	1
Red lentils (soaking)[b]	22	6.6*	–	–	7.0	1	2
Red lentils (cooked)[b]	22	1.7*	–	–	7.0	1	2
Red lentils (soaking)[b]	37	2.8*	–	–	7.0	1	2
Red lentils (cooked)[b]	37	1.4*	–	–	7.0	1	2
Black-eye beans (soaking)[b]	37	3.6*	–	–	7.0	1	2
Kidney beans (cooked)[b]	22	1.7*	–	–	7.0	1	2
Rice + 10% beef extract	15	3.3*	–	–	7.0	1	2
Rice + 10% beef extract	25	0.66*	–	–	7.0	4	3
Rice + 10% beef extract	30	0.33*	–	–	7.0	4	3
Rice + 10% beef extract	35	0.25*	–	–	7.0	4	3
Rice + 10% beef extract	45	0.91*	–	–	7.0	4	3
Rice + 10% beef extract	55	NG	–	–	7.0	4	3
TSB	10	NG	–	–	7.0	4	3
TSB	15	2.1–3.2	–	–	7.0	4	3
TSB	25	0.74–0.98	–	–	7.0	4	3
TSB	30	0.48–0.76	–	–	7.0	4	3
TSB	35	0.43–0.65	–	–	7.0	4	3
TSB	40	0.30–0.52	–	–	7.0	4	3
TSB	45	0.58–3.1	–	–	7.0	4	3
TSB	50	NG (2 strains) 2.4–3.6 (2 strains)	–	–	7.0	4	3
TSB	55	NG (1 strain) 5.5–7.2 (3 strains)	–	–	7.0	4	3
Reconstituted milk	8	3.6*	–	–	–	1	4
Reconstituted milk	30	0.85*	–	–	–	1	4
Infant formula	8	3.6*	–	–	–	1	4
Infant formula	30	1.00*	–	–	–	1	4
Rice	23	0.48	–	–	–	1	5
Rice	43	0.68	–	–	–	1	5
Liver sausage	8	12.4*	–	–	5.9–6.1	1	6
Yeast extract phosphate broth plus glucose[c]	8	–	–	NG after 4 months	7.0	1	7
Yeast extract phosphate broth plus glucose[c]	12	–	–	Turbidity 4–5 d	7.0	1	7
Yeast extract phosphate broth plus glucose[c]	30	–	–	Turbidity 18–20 h	7.0	1	7
Skim milk	40	0.5*	–	–	6.6	Strain No. 7	8
Ground beef[b]	1	–	−1 log/>14 d	Death	–	5	9
Ground beef[b]	4.5	–	−1 log/>7 d	Death	–	5	9
Ground beef[b]	7	–	−1 log/>5 d	Death	–	5	9
Ground beef[b]	12.5	–	−1 log/>2 d	Death	–	5	9
Milk	30	0.44*	–	–	6.8	1	10
Pumpkin pie	4	–	–	NG/ND/84 h	–	1	11
Pumpkin pie	25	0.86*	–	–	–	1	11
Pumpkin pie	35	–	–	NG/ND/84 h	–	1	11
Boiled rice	22	0.43–0.84	–	–	–	8	12
Reconstituted dry milk	20	1.33*	–	–	–	–	13
Reconstituted dry milk	30	0.55*	–	–	–	–	13
BHI + 1% glucose	30	0.48*	–	–	6.8	4	14
BHI + 1% starch	30	0.55–0.60*	–	–	6.8	4	14

† Does not include psychrotrophic strains
* Approximate growth rates from published data
[a] Additional ingredients include: (g/l) 10 glucose, 3.0 K_2HPO_4, 1.0 KH_2PO_4
[b] Vegetative cells
[c] Initial inoculum 1.3×10^3 CFU/ml

BHI, Brain Heart Infusion
NG/ND, no growth, no death
NG, no growth within 1 day
TSB, trypticase soy broth

1. Beuchat *et al.* (1980)
2. Blakey and Priest (1980)
3. Johnson *et al.* (1983)
4. Helmy *et al.* (1984)
5. Morita and Woodburn (1977)
6. Asplund *et al.* (1988)
7. Mol (1957)
8. Mikolajcik *et al.* (1973)
9. Goepfert and Kim (1975)
10. Wong *et al.* (1988)
11. Wyatt and Guy (1981)
12. Parry and Gilbert (1980)
13. Rodriguez and Barrett (1986)
14. Garcia-Arribas and Kramer (1990)

Table 1b Temperature (toxin production) 4–30°C

Substrate	Temp. (°C)	Toxin type	Time to formation	Conc.	a_w	pH	Other	Inoc. level (CFU/ml)	No. of strains	Ref.
BHI	25	Diarrhoeal*	–	≥2 ng/ml	–	–	Agitation (200 rpm)	–	71	1
Skim milk	21	Diarrhoeal*	–	15–65 ng/ml	–	–	Static	–	3	1
BHI + glucose	30	Tissue culture[a] toxicity	5–7 h	–	–	8.0	Static	10^4	45	2
Skim milk	30	Tissue culture[a] toxicity	7 h	–	–	6.6	Static	10^4	60	2
BHI + glucose	15	Tissue culture[a] toxicity	68–92 h	–	–	8.0	Agitation (200 rpm)	10^4	1	2
Skim milk	15	Tissue culture[a] toxicity	68–92 h	–	–	6.6	Agitation (200 rpm)	10^4	2	2
BHI + glucose	8	Tissue culture[a] toxicity	67 h	–	–	8.0	Agitation (200 rpm)	10^4	1	2
Skim milk	8	Tissue culture[a] toxicity	67–96 h	–	–	6.6	Agitation (200 rpm)	10^4	1	2
Whipped cream	8	Tissue culture[a] toxicity	72–96 h	–	–	7.4	–	10^4	1	2
Pasteurized milk	30	Tissue culture[b] toxicity	8 h	–	–	–	–	10^4	B4ac	3
Pasteurized milk + PO_4 buffer, pH 7.0	30	Tissue culture[b] toxicity	8 h	–	–	7.0	–	10^4	B4ac	3
BHI	30	Tissue culture[b] toxicity	16 h	–	–	–	–	10^4	1	3
BHI/milk	4	Diarrhoeal*	24 d	>4 ng/g	1.0	5.8	–	10^1	–	4
BHI/milk	4	Diarrhoeal*	12 d	>4 ng/g	1.0	5.8	–	10^1	–	4
BHI/milk	17	Diarrhoeal*	2 d	>4 ng/g	1.0	5.8	–	10^1	–	4
Minced meat	4	Diarrhoeal*	24 d	>4 ng/g	0.97	6.2	–	10^1		4
Minced meat	7	Diarrhoeal*	12 d	>4 ng/g	0.97	6.2	–	10^1	–	4
Minced meat	17	Diarrhoeal*	2 d	>4 ng/g	0.97	6.2	–	10^1	–	4
Lasagne	4	Diarrhoeal*	24 d	>4 ng/g	0.95	5.8	–	10^1	–	4
Lasagne	7	Diarrhoeal*	11 d	>4 ng/g	0.95	5.8	–	10^1	–	4
Lasagne	17	Diarrhoeal*	2 d	>4 ng/g	0.95	5.8	–	10^1	NS	4
Rice meal	4	Diarrhoeal*	24 d	>4 ng/g	0.97	6.3	–	10^1	NS	4
Rice meal	7	Diarrhoeal*	11 d	>4 ng/g	0.97	6.3	–	10^1	NS	4
Rice meal	17	Diarrhoeal*	2 d	>4 ng/g	0.97	6.3	–	10^1	NS	4
BHI	7	Diarrhoeal*	11 d	>4 ng/g	–	–	–	ca. 10^3	3	4
BHI + glucose	30	VPR	6 h	–	–	6.8	Agitation (200 rpm)	10^5	4	5
BHI + starch	30	VPR	6 h	–	–	6.8	Agitation (200 rpm)	10^5	4	5
BHI + Tris–HCl	30	VPR	8–15 h	–	–	8.8	Agitation (200 rpm)	10^5	4	5
BHI + piperazine –HCl	30	VPR	8 h	–	–	5.0	Agitation (200 rpm)	10^5	4	5

* A reverse passive latex agglutination assay with dubious specificity was used; results are questionable
[a] Tissue culture, HeLa, Vero, and human embryonic lung cells
[b] Tissue culture, Chinese Hamster Ovary cells
VPR, vascular permeability reaction activity
NS, not stated

1. Griffiths (1990)
2. Christiansson *et al.* (1989)
3. Wong *et al.* (1988)
4. van Netten *et al.* (1990)
5. Garcia-Arribas and Kramer (1990)