The relationship between infecting dose and severity of disease in reported outbreaks of salmonella infections

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SUMMARY

The relationship between size of the infecting dose and severity of the resulting disease has been investigated for salmonella infections by reanalysis of data within epidemics for 32 outbreaks, and comparing data between outbreaks for 68 typhoid epidemics and 49 food-poisoning outbreaks due to salmonellas. Attack rate, incubation period, amount of infected food consumed and type of vehicle are used as proxy measures of infecting dose, while case fatality rates for typhoid and case hospitalization rates for food poisoning salmonellas were used to assess severity. Limitations of the data are discussed. Both unweighted and logit analysis models are used.

There is no evidence for a dose-severity relationship for *Salmonella typhi*, but evidence of a correlation between dose and severity is available from within-epidemic or between-epidemic analysis, or both, for *Salmonella typhimurium*, *S. enteritidis*, *S. infantis*, *S. newport*, and *S. thompson*. The presence of such a relationship affects the way in which control interventions should be assessed.

INTRODUCTION

In outbreaks of communicable disease it is commonly observed that many are exposed, a proportion become infected, some of these are ill and few die. While it is well established for many infections that the larger the infective dose or inoculum the greater the chance of being infected, the relation between infecting dose and severity of resulting illness is much less clear. This is mainly because it is usually impossible to measure individual infecting doses in human disease outbreaks. If there is a dose-effect, public health interventions can be expected to have a greater impact on severe than on total disease [1]. Knowledge of an effect is therefore important both for implementing and evaluating public health programmes. This study investigates the relation between infecting dose and severity of disease for salmonella outbreaks in man by comparative analysis of published data. Various proxy measures are used for dose and severity.

Direct evidence concerning the dose-severity relationship in man comes from the few volunteer experiments, chiefly carried out during research on typhoid vaccines. As the dose of *Salmonella typhi* increased so did the attack rate, while the median incubation period decreased [2]. The authors state that there was no

association between dose and severity of symptoms, but give no details. McCullough and Eisele [3-6] gave varying doses of several non-typhoid salmonellas to volunteers in experiments designed to test pathogenicity and to determine the minimal infective dose. As the dose increased, the proportion with positive faecal cultures and, at higher doses, with clinical disease both increased, but there were too few ill volunteers with each strain for any further conclusions on dose and severity to be drawn, and interpretation is complicated by the use of many volunteers for more than one feeding.

The only other direct evidence is from animal experiments. The interval from inoculation of mice with salmonellas to their death is negatively, linearly related to the logarithm of the dose of bacteria, at least for doses above the LD_{50} , the dose which kills half of those exposed [7-10], and a similar relationship is found in chicks [11]. Among mice, the case-fatality rate increases with dose [12]. It is difficult to study disease severity, short of death, using small animals, but in one study of chickens the duration of diarrhoea increased with salmonella dose [13]. For calves there appears to be an increase in severity with dose for several salmonella serotypes, but calves are expensive and the sample sizes very small [14-17].

For outbreak studies indirect measures are needed. The ingested dose is not known directly, but several proxy measures of relative dose are available. The most obvious is the amount of infected food consumed, but this is rarely recorded and the organisms are likely to be unevenly distributed in the food. Typhoid can be conveyed by food or water: it seems likely that the infecting dose in water-borne epidemics is lower [18]. In the volunteer experiments dose was related to attack rate and incubation period [2-6]. Where information on relative dose, attack rate and incubation is available in reports of natural outbreaks, the same associations can be found for both typhoid [19, 20] and the food-poisoning salmonellas [21].

Blaser and Newman [22] and Naylor [23] both suggest a negative correlation between attack rate and incubation period for several typhoid epidemics, which could be due to the common effects of dose, though variation in salmonella virulence between epidemics would give a similar result.

METHODS

In this meta-analysis of human salmonella outbreaks we have used four proxy measures of dose, amount of food, type of vehicle, attack rate and incubation period, in assessing whether dose influences severity of disease. Whilst various measures of severity are used for within-epidemic analysis, for comparisons of epidemics the case fatality rate is used for typhoid and hospitalization rate for other salmonellas, for reasons discussed below.

The criteria for selection of studies for re-analysis were as follows. Published reports were identified that gave data on severity and on a proxy measure of dose. They were found by searching the Bulletin of Hygiene, later Abstracts of Hygiene (from 1926), The Lancet (1920-45), The American Journal of Hygiene (1921-64), the British Local Government Board, Medical Officer's Report (later the Reports to the Local Government Board on Public Health and Medical Subjects and then

the Ministry of Health Reports on Public Health and Medical Subjects, from 1900), the National Communicable Diseases Center, later the Center for Disease Control Salmonella Surveillance Reports (1964-76) and the Morbidity and Mortality Weekly Reports (from 1976): any references from these journals, or from already identified articles, which it was thought might contain sufficient data were followed up. For the analysis of single epidemics, all identified reports that gave data on severity and on a proxy measure of dose were included. Where the data were anecdotal the reports are only mentioned briefly, as there is likely to be a bias towards inclusion of positive findings in a report.

For comparison between epidemics, the selection criteria for typhoid and for the other salmonellas differ because of the necessary use of different proxy measures of severity. Within the criteria, all located published outbreaks were included.

For typhoid, case fatality rate was chosen as an outcome measure which could be extracted from reports and could be compared between epidemics. As case fatality rates are much lower with antibiotic therapy, outbreaks occurring after 1945 were excluded. Common source typhoid epidemics were identified in the published literature and included in the study if they contained sufficient information on case fatality rate and attack rate or incubation period and involved at least eight cases. Outbreaks among hospital patients were excluded. As information on incubation period was scarce, post-war epidemics where the incubation period was given were also identified. They have only been included in the analysis when case fatality rate is not being considered.

Correlations were sought between: attack rate (AR) and incubation period; attack rate and case fatality rate (CFR); and incubation period and case fatality rate. For reasons addressed in the discussion the initial analysis was carried out unweighted (each epidemic carrying equal weight regardless of size). As an attempt to separate epidemics with more accurate information, a subgroup of pre-war epidemics was identified where the population exposed was well defined (such as guests at a reception, or people supplied with milk from one farm). For this subgroup weighted analysis was done using logistic regression. The models used were:

$$\text{Logit AR} = \text{Constant} + \beta(\text{Incubation}),$$

$$\text{Logit CFR} = \text{Constant} + \beta'(\text{Incubation}),$$

$$\text{Logit CFR} = \text{Constant} + \beta''(\text{AR}).$$

For the food poisoning salmonellas we have again used attack rates and incubation periods as measures of dose. Fatalities from non-typhoid salmonellas are unusual, and descriptions of cases are not detailed enough for any symptom-based measure of morbidity to be used. The only readily available measure of severity is the number of cases requiring hospitalization. Since this is obviously time- and culture-dependent we have only used epidemics reported in the National Communicable Disease Center (later Center for Disease Control) Salmonella Surveillance Reports. The hospitalization rate was taken as the proportion of cases who were hospitalized. Surveillance reports of common source outbreaks from the period 1964-74 were included if they contained sufficient information and involved more than eight people. Outbreaks involving hospital patients or mixed infections were excluded.

Correlations were sought between: attack rate and hospitalization rate; median incubation period and hospitalization rate; and attack rate and median incubation period. The analysis was carried out using unweighted linear regression and logistic regression. The models used for the logistic regression are:

$$\text{Logit hospitalization rate} = \text{constant} + \beta(\text{attack rate}),$$

$$\text{Logit hospitalization rate} = \text{constant} + \beta'(\text{incubation}).$$

RESULTS

Analyses of single epidemics

Amount of food

For typhoid only two reports allow comparison of amount of food with outcome. In an outbreak following a school picnic the case fatality rate was 3/17 for those who had whole portions of the affected ice cream and 0/6 for those with half portions ($P = 0.5$ Fisher's 2-tailed test) [20]. The other report concerned a milk-borne outbreak involving 68 cases [24]. The author noted that among those who were ill, those who only took milk in their tea or coffee had very mild attacks.

For the food poisoning salmonellas we have found 11 reports which provide information on amount of food and severity. Mintz and colleagues [21] provide the most detailed breakdown of outcome by amount of food consumed, in an outbreak of 171 cases of *S. enteritidis* infection due to contaminated Hollandaise sauce. As the amount of sauce used increased, there were increases in the proportion of cases with body aches, nausea and vomiting, the maximum number of stools passed per 24 h, and acute weight loss, but not in duration of illness. Taylor [25] describes a small family outbreak of *S. typhimurium* in which the person who had eaten the most of the affected vehicle died. In five other reports, although it is stated that those who ate more had more severe disease, no supporting evidence is given [26-30].

Four reports failed to find an association. In an *S. typhimurium* outbreak affecting nearly 200 people, there were no differences in the mean maximum stool frequency or in the duration of illness for those who ate one or more pieces of the chicken vehicle [31]. However, the attack rate was not related to the number of pieces of chicken eaten either, so the bacteria may have been unevenly distributed. Two other negative reports refer to meat pies. In the first the pies were baked in two separate lots on different days, so uniform contamination is unlikely [32]. In the second, most of those who had severe disease had eaten the smaller pies but had kept them unrefrigerated for 24 h [33]. The last report refers to only six cases [34].

Four anecdotal reports suggest that food eaten later (after allowing time for bacteria to multiply) gave rise to more severe disease [28, 35-37].

Attack rate and outcome

In an extended water-borne typhoid outbreak in Bolton-upon-Deane in 1921 attack rates and case fatality rates were reported by district, and showed no

particular pattern [38]. We have found no other studies of salmonella where attack rate and measures of severity are given by area.

Incubation period and outcome

In five reports of typhoid outbreaks individual incubation periods can be related to outcome [20, 39–42]. In some, including the two larger outbreaks [20, 39], the incubation periods for those who died were on average slightly shorter than for the others, but in none of the epidemics did the differences approach significance at the 5% level.

For the food poisoning salmonellas the picture is rather different. Of nine reports which give sufficient details, only one [43] failed to find an association between incubation period and severity. In an outbreak of *S. newport* food-poisoning in Sweden [44] information was available on 161 people; those with shorter incubation periods had more severe illnesses. In a large outbreak of *S. thompson* food-poisoning in Tennessee onset times were on average earlier in the 51 who were hospitalized than in 72 others [45]. Balice [26] describes a severe outbreak of *S. typhimurium* in Italy. All 83 people who ate the affected food became ill and there were five deaths. The mean incubation period overall was 21 h (range 8–30 h), and for the five who died it was 14 h. However, in an outbreak due to *S. newport* where information was available for 105 cases, it was noted that the median incubation period was 29 h overall, and 30 h for those with 'severe illness', defined by the number of different symptoms experienced. The number of cases in this group is not stated. It was also stated that there was no relationship between the length of the incubation period and the duration of illness [43]. The other five reports all suggest an association, but are based on small numbers of cases or have small numbers of deaths as their only outcome measure [32, 46–49].

Comparisons between epidemics: typhoid

Sixty-nine typhoid epidemics fulfilled the criteria, including eight post-war epidemics (see Appendix 1). Most were from Britain or the United States. Thirty-five were water-borne. Incubation periods were available for 27 epidemics, including 19 pre-1945 epidemics. The median incubation period was used whenever it was given. Attack rates were available for all but four of the epidemics.

The distributions of attack rates, incubation periods and case fatality rates are shown in Fig. 1. The association between them are shown in Figs 2 and 3. A log scale is used for the attack rate as the distribution of attack rates is skewed to the right. High attack rates were associated with short incubation periods but no significant correlations with case fatality rate were found.

Water-borne epidemics had longer incubation periods and lower attack rates. There was no difference in case fatality rates between water- and food-borne epidemics (Table 1). When the vehicle (water or food) was added to the regression equations, in a multiple regression model, the correlation between incubation period and attack rate was no longer significant, and the regression coefficient was reduced to -2.8 (95% confidence interval -6.1 to 0.5). There was still no association between case fatality rate and either attack rate or incubation period. The analysis was repeated for circumscribed pre-war epidemics where the

Fig. 1. Typhoid epidemics used in the comparison study. (a) Attack rates for 65 epidemics. (b) Incubation periods for 26 epidemics. (c) Case fatality rates for 61 pre-1945 epidemics.

Fig. 2. The relationship between attack rate and incubation period for 23 typhoid epidemics. Each square represents an epidemic. □, water-borne; ■, food-borne. Correlation coefficient = -0.55 (95% confidence interval (CI) -0.78 to -0.17); regression coefficient = -4.01 (95% CI -6.64 to -1.38); constant = 18.92 ; $t = 2.99$; $p < 0.001$.

population exposed was well defined. Thirty-one epidemics fulfilled this criterion. No associations between incubation period, attack rate and case fatality rate were found in the unweighted analysis.

Logistic regression analysis for this subgroup of circumscribed epidemics showed a negative association between incubation and attack rate based on 11 epidemics which were all food-borne (likelihood ratio statistic (LRS) 93.2, one degree of freedom (D.F.), $P < 0.001$, proportion of deviance explained = 15%).

Fig. 3. The relationship between case fatality rate and (a) attack rate (for 58 pre-1945 typhoid epidemics) and (b) incubation period (for 19 pre-1945 typhoid epidemics). Each square represents an epidemic.

Table 1. Comparisons between food and water-borne typhoid epidemics

	No.	Mean	95% confidence interval	P
Incubation period (days)				
Water-borne	8	18.5	(15.2-21.8)	0.007 (t test)
Food-borne	18	13.2	(11.0-15.4)	
Attack rate (%)*				
Water-borne	34	3.8	(2.3-6.3)	< 0.001 (t test)
Food-borne	28	16.7	(10.8-25.9)	
Case fatality rate (%)†				
Water-borne	32	10.3	(8.4-12.2)	0.8 (Kruskal-Wallis)
Food-borne	26	11.4	(8.0-14.9)	

* Geometric mean given.

† Pre-1945 epidemics only.

Incubation period showed a just significant positive association with case fatality rate based on 13 epidemics (LRS 4.4, 1 D.F., $P = 0.04$). There was no association between attack rate and case fatality rate.

There was a non-significant negative correlation between case fatality rate and the date of the epidemic. When the year of the outbreak was included in multiple regression or logistic regression models between case fatality rate and incubation period or attack rate the regression coefficients hardly changed.

Comparisons between epidemics: food-poisoning salmonellas

Sufficient numbers of suitable reports were available for analysis for four different salmonellas: *S. typhimurium*, *S. enteritidis*, *S. thompson*, *S. infantis*. Details of the epidemics are given in Appendix 2. All except one epidemic (of *S. typhimurium*) were food-borne.

Plots of hospitalization rates by attack rates are shown in Fig. 4. The results of fitting the logistic regression model are given in Table 2.

Fig. 4. The relationship between hospitalization rate and attack rate for four food-poisoning salmonellas. Each square represents an epidemic. x, Epidemics of less than 20 cases; □, epidemics of 20–100 cases; ■, epidemics of over 100 cases (a) *S. typhimurium* (16 epidemics); (b) *S. enteritidis* (11 epidemics); (c) *S. infantis* (7 epidemics); (d) *S. thompson* (8 epidemics).

S. typhimurium. Information was available for 16 epidemics. Linear regression showed no relationship between attack rate and hospitalization rate but logistic regression showed a positive correlation, giving the model:

$$\text{Logit HR} = -5.6 + 0.0406 (\text{AR}),$$

where HR is hospitalization rate and AR is attack rate. When the one large water-borne epidemic was excluded, the coefficient decreased to 0.0201 (s.e. 0.0058) but the model remained highly significant: LRS = 12.5, 1 D.F., $P < 0.001$.

S. enteritidis. The linear regression, based on 11 epidemics, did not show a significant association, but again logistic regression showed a positive correlation, giving the model:

$$\text{Logit HR} = -3.5 + 0.0223 (\text{AR}).$$

Table 2. *The association between hospitalization rate and attack rate for salmonellas: logistic regression results*

Serotype	Coefficient	Standard error	Constant	LRS*	D.F.†	P	Deviance explained (%)
typhimurium	0.0406	0.0028	-5.6	135	1	< 0.001	58.7
enteritidis	0.0223	0.0063	-3.5	11.8	1	< 0.001	10.7
infantis	0.0415	0.0072	-3.6	37.2	1	< 0.001	43.6
thompson	-0.0069	0.0043	-0.96	2.5	1	0.1	

* Likelihood ratio statistic.

† Degrees of freedom.

After excluding the one outlying epidemic with a high hospitalization rate (Fig. 4) the association was lost.

S. infantis. The linear regression model, based on seven epidemics, was just significant, but is influenced by a small epidemic with high attack and hospitalization rates. (Correlation coefficient = 0.75, regression coefficient = 0.71 (95% confidence interval 0.16-1.25), constant = -7.96, $t = 2.55$, $P = 0.05$). Logistic regression also showed a positive correlation, giving the model:

$$\text{Logit HR} = -3.6 + 0.0415 (\text{AR}).$$

After excluding the small epidemic with the high attack and hospitalization rates, the coefficient in the logistic regression model decreased to 0.0237 (s.e. 0.0094) and the strength of the association was reduced, but it remained significant (LRS = 6.2, 1 D.F., $P = 0.01$).

S. thompson. The scatter plot (based on eight epidemics) shows no trend in the results, and neither linear nor logistic regression models had coefficients which were significantly different from zero.

Incubation periods were only available for a few epidemics of each serotype. For *S. typhimurium*, six epidemics contained information on both incubation and hospitalization rate: no association was found using linear or logistic regression. Even less information was available for the other serotypes.

DISCUSSION

For typhoid the results confirm the suspected relationship between incubation period and attack rate. Since there is no evidence that more virulent forms of typhoid are found in food than in water, the long incubation periods and low attack rates found in water-borne epidemics suggest that the dose in these epidemics is, on average, smaller. By contrast, correlations between attack rate or incubation period and case fatality rates were not found (with one exception), even though both dose effects and any differences in virulence would be expected to lead to such correlations.

There are, however, limitations to the typhoid data. The attack rate depends on both full ascertainment of cases and correct ascertainment of those at risk, here taken as those exposed during the epidemic. Immune status was usually unknown. The most accurate estimates of those exposed are those obtained from circumscribed epidemics occurring after specific meals or at a camp where everyone can be traced and those who consumed a particular food or drank the

water can be identified. Milk-borne epidemics where the numbers of people on the milk round is known give reasonable figures. When the domestic water supply is the source, the number of people using the supply is only an approximate estimate, and those who avoid being truly exposed by buying or boiling their drinking water is unknown. Also, it is unlikely that the whole of the supply is significantly contaminated. Full ascertainment of cases is also difficult, but again it is likely to be most complete for the most circumscribed epidemics where individuals are actively traced. Large epidemics rely on notification of cases which will be incomplete.

The incubation period can be estimated only for point source epidemics and then only if dates of onset of illness rather than dates of notification are available. Late cases may be missed and secondary cases may be mistakenly included (leading to under- and over-estimates of the median incubation period respectively). The median incubation has been used as the epidemic curve is approximately log-normal, and it is usually the measure quoted. For a few epidemics where only the mode or 'average' was given, that was used instead; they are usually similar (see Appendix 1).

Identification of deaths from typhoid is probably more complete than identification of cases, leading to overestimation of the case fatality rate, to an extent which will vary from epidemic to epidemic, depending on the completeness of case ascertainment. It is a crude measure of severity, particularly as the numbers are small in some of the epidemics, and unmeasurable factors associated with the place of the outbreak would be expected to influence how many die.

Too few of the epidemics give sufficient information on the age, sex, or immune status of the people involved for these variables to be taken into account. The year of the epidemic may be expected to be associated with the case fatality rate, but would only be associated with incubation period or attack rate if methods of investigating or reporting outbreaks changed. Controlling for the year of the epidemic did not affect the results in the multiple regression analyses.

Epidemics could only be included in the study if they contained sufficient information. All identified epidemics which fulfilled the criteria were included, but they are not necessarily representative of all typhoid epidemics.

Although some of the data problems will lead to non-differential misclassification (and therefore to underestimation of associations) certain directions of bias appear likely: attack rates are likely to be unduly low in water-borne outbreaks due to both underestimation of cases and overestimation of susceptibles, and case fatality rates will be disproportionately high in epidemics with poor case ascertainment, which include most of the water-borne epidemics. It was felt that the large epidemics were often more inaccurate and more likely to be biased than the smaller epidemics so calculations are presented both weighted and unweighted.

Turning to the data, the finding of the expected correlation between attack rate and incubation period suggests that the data are not so crude as to be useless. Similarly, for water-borne epidemics, although the low attack rates may be due to bias, the longer incubation periods are unlikely to be, and the finding fits with the expected low dose of organisms in water.

The case fatality rates were the same in water as in food-borne epidemics. This could be true, reflecting no dose-effect, or could be due to bias giving falsely high

case fatality rates in water-borne outbreaks. Attack rates did not predict case fatality rates. This could be true or could reflect the falsely low attack rates and high case fatality rates of less well investigated outbreaks. No association was found when consideration was restricted to circumscribed outbreaks. Incubation period did not predict case fatality rate in most of the analyses. Again, although this may be true both variables, and particularly case fatality rate, are subject to considerable error in measurement. The weighted analysis of the circumscribed epidemics produced a surprising positive correlation between incubation period and case fatality rate. This was only just significant.

Overall, the comparison of data between typhoid epidemics provides no evidence of an association between dose (as measured by incubation period, attack rate or vehicle) and severity (as measured by the case fatality rate). While the data are too crude for an association to be excluded, this finding contrasts with the outbreaks due to other salmonellas but fits with the conclusions from Hornick's volunteer studies [2].

The results from food-poisoning salmonellas provide evidence of a correlation between attack rates and case-hospitalization rates. The evidence for incubation period was too rudimentary to be useful.

For the non-typhoid salmonellas the unweighted linear regression models are too simplistic as the epidemics range in size from 10 cases to several hundred (and to 14000 in the one water-borne epidemic – see Appendix 2). Unlike the typhoid data, and with the possible exception of the water-borne epidemic, there is no reason to believe that the figures in the larger epidemics are any less accurate than those in the smaller epidemics, so it seems appropriate to weight the epidemics according to size. The logistic regression model has the added advantage that it does not require the variables to be normally distributed, which is more appropriate given the small numbers involved. For three of the serotypes of salmonella the coefficients were highly significantly different from zero, and for *S. typhimurium* and *S. infantis* around 50% of the deviance in the results was explained by the model.

The epidemics studied here are not necessarily representative of all epidemics in the USA as not all are reported, and only the reports containing sufficient information could be included. Although all of the epidemics came from one country over a short period, criteria for hospitalization may have varied between epidemics, probably leading to under-estimation of any correlation. However, the hospitalization threshold may be higher in a large epidemic, which would bias the results in the weighted analyses. Lack of data prevented controlling for age, though those at the extremes of age are more likely to be hospitalized and may also have different attack rates.

The results for food poisoning salmonellas point to a positive correlation between attack rate and hospitalization rate at least for some types of salmonella. This is consistent with a dose effect whereby higher doses give higher attack rates and more severe disease, though differing virulence between different strains would give similar results. The results from the single epidemics tend to support the dose-severity correlation, though within an epidemic a correlation between incubation period and severity could be due to individual differences in susceptibility as well as dose.

Overall, therefore, for typhoid, there is no evidence of a dose-severity relationship. Attack rate and incubation period are both related to dose, but there is no evidence that they are in turn related to severity. The results for the other salmonellas are very different. The evidence as a whole, from individual epidemics and from the comparison of hospitalization rates, suggests that there is a dose-severity relationship at least for *S. enteritidis*, *S. typhimurium*, *S. infantis*, *S. newport* and *S. thompson*.

This contrast is reflected in the differing response to challenge of subjects who are partially immune. In volunteer experiments with typhoid, vaccines gave protection against low but not high challenge doses, but once clinical disease occurred the severity of the disease and the number of relapses were not altered by vaccination [2, 105]. This is consistent with dose influencing only the proportion of people becoming ill and not the severity of the infection. However, for the food-poisoning salmonellas, when subjects who had become ill were rechallenged, if they became ill again the severity of the illness was usually less than that of the initial illness, despite higher challenge doses being used [4]. This change in severity with immunity is consistent with a dose-severity relationship.

Knowledge of whether a dose-severity relationship exists is important in public health. If there is a relationship, then interventions such as improvements in sanitation, which can be expected to lower the dose, could have a greater impact on the number of severe cases than on the total number of cases [1], and in evaluation of such interventions it would be important to assess numbers of severe cases as well as changes in case incidence. Where there is no dose-severity relationship, or where it is unimportant compared to other determinants of variation in severity between individuals, the case incidence would suffice for assessment.

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REFERENCES

1. Esrey SA, Feachem RG, Hughes JM. Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities. Bull W H O 1985; **63**: 757-72.
2. Hornick RB, Greisman SE, Woodward TE, et al. Typhoid fever: pathogenesis and immunologic control. N Engl J Med 1970; **283**: 686-91, 739-46.
3. McCullough NB, Eisele CW. Experimental human salmonellosis. I. Pathogenicity of strains of *Salmonella meleagridis* and *Salmonella anatum* obtained from spray-dried whole egg. J Infect Dis 1951; **88**: 278-89.
4. McCullough NB, Eisele CW. Experimental human salmonellosis. II. Immunity studies following experimental illness with *Salmonella meleagridis* and *Salmonella anatum*. J Immunol 1951; **66**: 595-608.
5. McCullough NB, Eisele CW. Experimental human salmonellosis. III. Pathogenicity of strains of *Salmonella newport*, *Salmonella derby*, and *Salmonella bareilly* obtained from spray-dried whole egg. J Infect Dis 1951; **89**: 209-13.

6. McCullough NB, Eisele CW. Experimental human salmonellosis. IV. Pathogenicity of strains of *Salmonella pullorum* obtained from spray-dried whole egg. *J Infect Dis* 1951; **88**: 259–65.
7. Meynell GG, Meynell EW. The growth of micro-organisms *in vivo* with particular reference to the relation between dose and latent period. *J Hyg* 1958; **56**: 323–45.
8. Schutze H, Gorer PA, Finlayson MH. The resistance of four mouse lines to bacterial infection. *J Hyg* 1936; **36**: 37–49.
9. Robson HG, Vas SJ. Resistance of inbred mice to *Salmonella typhimurium*. *J Infect Dis* 1972; **126**: 378–86.
10. Hormaeche CE. Immunity mechanisms in Salmonella infections. PhD thesis, University of Cambridge, 1975.
11. Rao V, Chauhan HVS. The pathology and pathogenesis of *Salmonella stanley* infection in experimental chicks. *Res Vet Sci* 1987; **42**: 287–93.
12. Collins FM. Salmonellosis in orally infected specific pathogen-free C57B1 mice. *Infect Immun* 1972; **5**: 191–8.
13. Humphrey TJ, Baskerville A, Chart H, Rowe B, Whitehead A. *Salmonella enteritidis* PT4 infection in specific pathogen-free hens: influence of infecting dose. *Vet Rec* 1991; **129**: 482–5.
14. DeJong H, Ekdahl MO. Salmonellosis in calves – the effect of dose rate and other factors on transmission. *NZ Vet J* 1965; **13**: 59–64.
15. Robinson RA, Loken KI. Age susceptibility and excretion of *Salmonella typhimurium* in calves. *J Hyg* 1968; **66**: 207–16.
16. Wray C, Sojka WJ. Experimental *Salmonella typhimurium* infection in calves. *Res Vet Sci* 1978; **25**: 139–43.
17. Smith HW, Jones JET. Observations on experimental oral infection with *Salmonella dublin* in calves and *Salmonella choleraesuis* in pigs. *J Path Bact* 1967; **93**: 141–56.
18. Miner JR. The incubation period of typhoid fever. *J Infect Dis* 1922; **31**: 296–301.
19. Bernard RP. The Zermatt typhoid outbreak in 1963. *J Hyg* 1965; **63**: 537–63.
20. Cumming JG. An epidemic resulting from the contamination of icecream by a typhoid carrier. *JAMA* 1917; **68**: 1163–5.
21. Mintz ED, Cartter M, Zingesser J, Hadler J. Dose–response effects in a food-borne outbreak of *Salmonella enteritidis*, Connecticut. Presented at the Epidemic Intelligence Service Conference, April 1991.
22. Blaser MJ, Newman LS. A review of human salmonellosis. I. Infective dose. *Rev Infect Dis* 1982; **4**: 1096–106.
23. Naylor GRE. Incubation period and other features of food-borne and water-borne outbreaks of typhoid fever in relation to pathogenesis and genetics of resistance. *Lancet* 1983; **i**: 864–6.
24. Sirois JS. An outbreak of typhoid fever due to raw milk. *Canad Pub Health J* 1942; **33**: 168–73.
25. Taylor DN, Bopp C, Birkness K, Cohen ML. An outbreak of Salmonellosis associated with a fatality in a healthy child: a large dose and severe illness. *Am J Epidemiol* 1984; **119**: 907–12.
26. Balice A. Salmonellosis 'osimo' 1958. *Igiene e San Pubblica* 1958; **14**: 612–27.
27. Bierschenck H. Eine Lebensmittelvergiftung durch *Salmonella infantis* im Speiseeis. *Z Gesamte Hyg* 1962; **8**: 383–7.
28. De Blasi R, Scotti G. Alcuni aspetti della epidemiologia delle 'Salmonellosis'. *Riv Ital Igiene* 1950; **10**: 324–41.
29. Harding KM. An outbreak of food poisoning following the consumption of infected pork pie. *Medical Officer* 1966; **115**: 159–60.
30. Gomez Lus R, Gimenez Martinez A. Epidemia gastroenteritis aguda a *Salmonella typhimurium*. *Med Trop (Madrid)* 1965; **41**: 549–51.
31. Palmer SR, Watkeys JEM, Zamiri I, et al. Outbreak of Salmonella food poisoning amongst delegates at a medical conference. *J R Coll Physicians Lond* 1990; **24**: 26–9.
32. Miller AA, Nicol CGM, Ramsden F. An outbreak of food poisoning due to *Salmonella bovis* morbificans (Basenau) in which the vehicle of infection was meat pies. Ministry of Health. Reports on Public Health and Medical Subjects no. 96. London: HMSO, 1955.

33. Brockbank W, Metcalfe Brown C, Parker MT. Outbreak of food-poisoning due to *Salmonella aberdeen*. *Lancet* 1950; ii: 873-6.
34. D'Aoust J-Y. Infective dose of *Salmonella typhimurium* in cheddar cheese. *Am J Epidemiol* 1985; **122**: 717-20.
35. Cook GT, de Costabadie LP. Food poisoning associated with infected dried egg. *Monthly Bull Minist Health (London)* 1947; **6**: 177-80.
36. Semple AB, Turner GC, Lowry DMO. Outbreak of food poisoning caused by *Salmonella virchow* in spit-roasted chicken. *Br Med J* 1968; **2**: 801-3.
37. Möller A. Breslau-Gruppenerkrankung durch infizierte Hühnereier. *Zbl Bakt I Abt Orig* 1955; **164**: 535-9.
38. Shaw WV. Report to the Ministry of Health on an epidemic of enteric fever at Bolton-upon-Dearne. Ministry of Health. Reports on Public Health and Medical Subjects no. 12. London: HMSO, 1922.
39. Desranleau JM. An outbreak of typhoid fever traced to a wedding breakfast. *Can J Public Health* 1946; **37**: 244-8.
40. Lumsden LL. Outbreak of gastroenteritis and typhoid fever due to drinking water on excursion steamer. *Public Health Rep* 1912; **27**: 1960-71.
41. Bulstrode HT. Report upon alleged oyster-borne enteric fever and other illness following the Mayoral banquets at Winchester and Southampton, and upon enteric fever occurring simultaneously elsewhere, and also ascribed to oysters. Annual Report of the Medical Officer of the Local Government Board 1902-3. No. 9: 129-89.
42. Mollohan CS, Reid G. Typhoid fever in Colorado. *National Communicable Disease Center Salmonella Surveillance* 1967, no. 63: 4.
43. Horwitz MA, Pollard RA, Merson MH, Martin SM. A large outbreak of food borne Salmonellosis on the Navajo Nation Indian Reservation, epidemiology and secondary transmission. *Am J Public Health* 1977; **67**: 1071-6.
44. Bille B, Mellbin T, Nordbring F. An extensive outbreak of gastroenteritis caused by *Salmonella newport*. I. Some observations on 745 known cases. *Acta Med Scand* 1964; **175**: 557-67.
45. Fowinkle EW, Armes WH, Barrick JH, et al. A *Salmonella thompson* outbreak traced to barbecued pork - Tennessee. *Center for Disease Control Salmonella Surveillance* 1970, no. 99: 1-3.
46. Janeway CM, Goldfield M, Attman R, et al. Foodborne outbreak of gastroenteritis possibly of multiple bacterial etiology. *Am J Epidemiol* 1971; **94**: 135-41.
47. Holmes M, Runte V, Goldblatt EL. Fatal case of *Salmonella enteritidis* infection. *National Communicable Disease Center Salmonella Surveillance* 1967, no. 67: 6.
48. Anonymous. Update: *Salmonella enteritidis* infection and grade A shell eggs - United States. *MMWR* 1988; **37**: 490-6.
49. Hauser GH, Treuting WL, Brieffelh LA. An outbreak of food poisoning due to a new etiological agent - *Salmonella berta*. *Public Health Rep* 1945; **60**: 1138-42.
50. Scott HH. Some notable epidemics. London: Edward Arnold & Co, 1934.
51. Stallybrass CO. The principles of epidemiology and the process of infection. London: George Routledge and Son Ltd, 1931.
52. Greenwood M. Epidemics and crowd-diseases. London: Williams and Norgate Ltd, 1935.
53. Ledingham JCG. Report to the Local Government Board on the enteric fever 'carrier', being a review of current knowledge on this subject. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 43. London: HMSO, 1910.
54. Bracken HM, Bass FH, Westbrook FF. The Mankato typhoid fever epidemic of 1908. *J Infect Dis* 1911; **9**: 410-74.
55. Johnstone RW. Report to the Local Government Board upon outbreaks of enteric fever in Conway Rural District, Conway Urban District, and Llandudno Urban District, during 1908 and 1909. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 28. London: HMSO, 1910.
56. Carnwath T. Report to the Local Government Board upon an outbreak of enteric fever at Oakenshaw, in the urban district of Willington. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 59. London: HMSO, 1912.
57. Grover AL. An outbreak of typhoid fever in Cedar Falls, Iowa. *J Infect Dis* 1912; **10**: 388-408.

58. Wheaton SW. Report to the Local Government Board on enteric fever at Strood, in Rochester Borough, in 1912. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 79. London: HMSO, 1913.
59. Macewen HA. Report to the Local Government Board on an outbreak of enteric fever in Ringwood, 1912. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 74. London: HMSO, 1912.
60. Hutchinson JR. Report to the Local Government Board on an outbreak of enteric fever in the Borough of Colne (Lancashire), 1913. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 84. London: HMSO, 1913.
61. Jordan EO, Irons EE. The Rockford (Ill.) typhoid epidemic. *J Infect Dis* 1912; **11**: 21–43.
62. Ridlon JR. Investigation of typhoid fever at Texarkana, Ark. – Tex. (Milk outbreak). *Public Health Rep* 1912; **27**: 219–27.
63. Manby EP. Report to the Local Government Board upon an outbreak of enteric fever in the Urban District of Kenilworth. Reports to the Local Government Board on Public Health and Medical Subjects. New Series no. 92. London: HMSO, 1914.
64. Jordan EO, Irons EE. The Quincy (Illinois) typhoid epidemic. *J Infect Dis* 1913; **13**: 16–29.
65. Sawyer WA. Ninety-three persons infected by a typhoid carrier at a public dinner. *JAMA* 1914; **18**: 1537–42.
66. Geiger JC. A milk borne epidemic of typhoid fever due to the use of polluted water. *JAMA* 1917; **68**: 978–9.
67. Geiger JC, MacMillan A, Gillespie CG. A waterborne epidemic of typhoid fever. *JAMA* 1917; **68**: 1681–3.
68. Anonymous. A water-borne typhoid fever epidemic. *Lancet* 1921; *i*: 548–9.
69. Bundesen HN. Typhoid epidemic in Chicago apparently due to oysters. *JAMA* 1925; **84**: 641–50.
70. Lumsden LL. An outbreak of typhoid fever caused by a milkborne infection. *Public Health Rep* 1925; **40**: 1302–15.
71. Ramsey GH, Benning CH, Orr PF. An epidemic of typhoid fever following a church dinner. *Am J Public Health* 1926; **16**: 1011–6.
72. Murata S. On a prevalence of typhoid fever in Shizuoka Prefecture. *J Pub Health Assoc Japan* 1926; **2** (10): 1–6.
73. Anonymous. Epidemiology of typhoid fever in the Royal Navy. *Lancet* 1928; *ii*: 393.
74. Dean AS. The Olean City epidemic of typhoid fever in 1928. *Am J Public Health* 1931; **21**: 390–402.
75. Lessa G. Surto de febre typhoide de origem hydrica. *Brasil-Med* 1930; **44**: 1155–61.
76. Miner HE, Forsbeck FC. An outbreak of typhoid fever traced to a chicken salad infected by a carrier. *N Engl J Med* 1929; **200**: 440–1.
77. Garrido-Morales E, Costa Mandry O. Typhoid fever spread by water from a cistern contaminated by a carrier. *J Preventive Med* 1931; **5**: 351–5.
78. Anonymous. Typhoid in Yorkshire. *Lancet* 1932; *ii*: 1029–30.
79. Magliano G. Epidemia circoscritta di febbre tifoide di origine idrica. *Ann d'Igiene* 1935; **45**: 7–27. In: *Bull Hyg* 1935; **10**: 437.
80. Gomez Jimenez F. Un brote epidémico de fiebre tifoidea en Erla. *Rev Sanid Hig Pública (Madr)* 1934; **9** (1): 108–18.
81. Leeder FS. An outbreak of milk-borne typhoid fever. *Canad Pub Health J* 1932; **23**: 503–6.
82. Ritchie J, Armstrong E. A waterborne epidemic of typhoid fever. *J Hyg* 1932; **32**: 417–20.
83. Shaw WV. Report on an outbreak of enteric fever in the Malton Urban District. Ministry of Health. Reports on Public Health and Medical Subjects no. 69. London: HMSO, 1933.
84. Morris ES. An outbreak of typhoid fever at a Religious Convention probably caused by a 'carrier'. Rep Director General Public Health, New South Wales, for Year 1933: 47–51. In: *Bull Hyg* 1935; **10**: 777.
85. Hornung H. Eine Trunkwasser-Typhusepidemie in Swarzwald. *Arch Hyg Bakt* 1934; **113**: 158–69.
86. Anonymous. Sequel to a pilgrimage. *Lancet* 1935; *ii*: 452.
87. Johnson GE. Epidemiological features of a typhoid fever outbreak in West Philadelphia following a supper. *Am J Public Health* 1936; **26**: 913–17.
88. Anonymous. Typhoid after camping. *Lancet* 1936; *ii*: 654.

89. Watson Smith S. The 1936 outbreak of typhoid fever at Poole, Bournemouth and Christchurch. Bournemouth: Pardy and Son Ltd, 1942.
90. Roelcke K. Eine Gruppenerkrankung an Typhus durch Speiseeis. *Z Hyg Infektionskr* 1937; **119**: 549-57.
91. Lembecke PA, von Haesseler P. An epidemic of typhoid fever attributed to salad contaminated by a chronic typhoid carrier. *Am J Public Health* 1936; **28**: 1212-16.
92. Holden OM. The Croydon typhoid outbreak. *Public Health* 1939; **52**: 135-46.
93. Caudill FW. Small college suffers outbreak of water-borne typhoid fever. *Water Works Engineering* 1937; **90**: 106. In: *Bull Hyg* 1938; **13**: 106.
94. Landau D. Notes on a milk-borne typhoid outbreak. *S Afr Med J* 1938; **12**: 463-5.
95. Old HN, Gill SL. A typhoid fever epidemic caused by carrier 'bootlegging' oysters. *Am J Public Health* 1940; **30**: 633-40.
96. Constam ZF, Steiner H. Ueber eine Typhus-epidemie mit Vorkrankheit. *Schweiz Med Woch* 1945; **75**: 573-8. In: *Bull Hyg* 1945; **20**: 723-4.
97. Galea J. The typhoid epidemic of 1943 in Malta. Lux Press, 1944. In: *Bull Hyg* 1944; **19**: 927-8.
98. Jordan J, Everley Jones H. Typhoid fever in immunised personnel. *Lancet* 1945; **ii**: 333-5.
99. Marmion DE, Naylor GRE, Stewart IO. Second attacks of typhoid fever. *J Hyg* 1953; **51**: 260-7.
100. Neill WA, Martin JD, Belden EA., Trotter WY. A widespread epidemic of typhoid fever traced to a common exposure. *N Engl J Med* 1958; **259**: 667-72.
101. Caraway CT, Bruce JM. Typhoid fever epidemic following a wedding reception. *Public Health Rep* 1961; **76**: 427-30.
102. Mallory A, Belden EA, Brachman PS. The current status of typhoid fever in the United States and a description of an outbreak. *J Infect Dis* 1969; **119**: 673-6.
103. Taylor A, Santiago A, Gonzalez-Cortes A, Gangarosa EJ. Outbreak of typhoid fever in Trinidad in 1971 traced to a commercial icecream product. *Am J Epidemiol* 1974; **100**: 150-7.
104. Hanson SM, Bender G, Schrack WD, Goldenson RH. *S. typhi* - Coatsville Pennsylvania. Center for Disease Control Salmonella Surveillance 1972, no. 113: 3-4.
105. Hornick RB, Woodward TE. Appraisal of typhoid vaccine in experimentally infected human subjects. *Trans Am Clin Climatol Assoc* 1966; **78**: 70-8.

Appendix 1. *Typhoid epidemics*

Ref.	Year	Place	Vehicle	Incubation median (days)	Attack rate % (no.)	Case fatality rate % (no.)
50	1881	Blackburn	Water		0.61 (?/20000)	13.19 (24/182)
51	1885	Pennsylvania	Water		12.55 (1004/8000)	11.35 (114/1004)
50	1893	Worthing	Water		8.33 (1298/15579)	12.48 (162/1298)
50	1893	Worthing	Water		3.87 (113/2919)	21.24 (24/113)
52	1897	Maidstone	Water		8.08 (?/20000)	6.81 (132/1938)
41	1902	Winchester	Oysters*	14	8.20 (10/122)	40.00 (4/10)
41	1902	Southampton	Oysters*	16	9.17 (10/109)	10.00 (1/10)
53	1904	Brislington	? Carrier*		72.22 (26/36)	7.69 (2/26)
50	1904	Lincoln	Water		1.95 (1058/54204)	11.81 (125/1058)
54	1908	Minnesota	Water	15	4.40 (440/10000)	6.82 (30/440)
55	1909	Conway	Milk*		11.11 (26/234)	18.18 (10/55)
56	1910	Oakenshaw	Milk*		11.78 (53/450)	7.94 (5/63)
57	1911	Iowa	Water		2.83 (170/6000)	10.00 (17/170)
58	1912	Strood, Kent	Water		0.51 (69/13428)	11.59 (8/69)
59	1912	Ringwood, Hants	Water*		50.00 (23/46)	17.39 (4/23)
60	1912	Colne	Milk*		7.44 (67/900)	8.57 (6/70)
61	1912	Rockford, Ill.	Water	20	0.42 (199/47500)	12.06 (24/199)
40	1912	Iowa	Water	14	0.71 (11/1550)	27.27 (3/11)
62	1912	Texas	Milk*		1.28 (25/1950)	2.94 (1/34)
63	1913	Kenilworth	Water		0.84 (44/5258)	9.09 (4/44)
64	1913	Quincy, Ill.	Water	26	0.55 (202/37000)	7.92 (16/202)
65	1914	Hanford, CA	Spaghetti*	7	56.67 (85/150)	3.23 (3/93)
66	1915	Colusa, CA	Milk*	12	3.58 (23/643)	0.00 (0/23)

Appendix 1. (cont.)

Ref.	Year	Place	Vehicle	Incubation median (days)	Attack rate % (no.)	Case fatality rate % (no.)
20	1916	Helm, CA	Icecream*	6	95.83 (23/24)	13.04 (3/23)
67	1917	California	Water		20.00 (52/260)	0.00 (0/52)
68	1920	Salem, Ohio	Water		7.85 (785/10000)	1.53 (12/785)
38	1921	Bolton-Dearne	Water		0.67 (137/20497)	11.68 (16/137)
38	1921	Bolton-Dearne	Water		7.26 (260/3581)	11.15 (29/260)
69	1924	Chicago	Oysters	12		12.40 (16/129)
75	1924	Tennessee	Milk*		33.33 (100/300)	8.00 (8/100)
70	1925	Michigan	Food*	13	14.00 (35/250)	17.14 (6/35)
72	1925	Japan	? Food*	18	48.68 (37/76)	20.45 (9/44)
51	1926	Hanover	Water		0.59 (2500/425000)	10.40 (260/2500)
51	1927	Montreal	Milk		5.10 (3601/70576)	10.66 (533/5002)
73	1928	Royal Navy	Lettuce*	12†	10.22 (95/930)	7.37 (7/95)
74	1928	New York State	Water		1.15 (248/21599)	10.08 (25/248)
75	1929	Rio de Janeiro	Water*		18.31 (39/213)	12.82 (5/39)
76	1929	Massachusetts	Chicken*	19	44.62 (29/65)	6.90 (2/29)
77	1931	Porto Rica	Water*		33.33 (10/30)	10.00 (1/10)
78	1932	Denby Dale	Water		5.07 (71/1400)	8.45 (6/71)
79	1932	Genoa	Water		2.51 (42/1672)	7.14 (3/42)
80	1932	N Spain	Water		7.79 (87/1117)	4.60 (4/87)
81	1932	Massachusetts	Milk*		39.68 (25/63)	7.14 (2/28)
82	1932	Dumfriesshire	Water		5.50	3.13 (2/64)
83	1933	Malton, Yorks	Water		5.22 (235/4500)	8.52 (23/270)
84	1933	New South Wales	Food*		11.00 (33/300)	27.27 (9/33)
85	1934	Black Forest	Water*	17		9.09 (3/33)
86	1935	Lourdes	?		6.82 (75/1100)	5.33 (4/75)
87	1935	Philadelphia	Salad*		33.77 (77/228)	6.98 (6/86)
88	1936	England	?*		35.00 (14/40)	14.28 (2/14)
89	1936	Bournemouth	Milk	14‡	5.18 (518/10000)	9.85 (51/518)
90	1936	Mittelbaden	Icecream*	13		0.00 (0/24)
91	1936	Massachusetts	Salad*	9	37.14 (13/35)	7.69 (1/13)
92	1937	Croydon	Water		0.75 (?/42000)	13.87 (43/310)
93	1937	Kentucky	Water*		22.86 (16/70)	12.50 (2/16)
94	1938	S. Africa	Milk*		30.06 (52/173)	20.90 (14/67)
95	1939	Louisiana	Oysters*	9	75.00 (87/116)	9.20 (8/87)
24	1942	Canada	Milk*		27.50 (66/240)	10.29 (7/68)
96	1943	Switzerland	Water*		33.75 (27/80)	3.70 (1/27)
97	1943	Malta	Water		0.99 (1275/)	12.20 (156/1275)
98	1944	Middle East	? Food*		34.35 (79/230)	11.25 (9/80)
99	1950	Egypt RAF Unit	Mock cream	7†	34.06 (234/687)	0.0 (0/234)
100	1958	Monark	Water	21	6.18 (34/550)	2.94 (1/34)
101	1961	Louisiana	Chicken	20	32.00 (31/97)	0.00 (0/31)
19	1963	Zermatt	Water	17	4.37 (437/10000)	0.69 (3/437)
102	1969	Audrain, USA	Water	18†	23.36 (25/107)	0.00 (0/25)
103	1971	Trinidad	Icecream	19	1.20	0.00
104	1971	Pennsylvania	? Food	17	25.38 (33/130)	6.06 (2/33)

* Circumscribed pre-1945 outbreaks (see text).

† Modal incubation period.

‡ 'Average' incubation period.

Appendix 2. *Salmonella* epidemics from CDC *Salmonella* Surveillance

Ref.*	Place	Date	Vehicle	Attack rate % (no.)	Hospital rate % (no.)	Incubation median (hours)
<i>S. typhimurium</i>						
30:8	New Jersey	1964	Wedding	14.9 (35/235)		15
33:4	Michigan	1964	Icecream	81.8 (9/11)		19
38:2	California	1965	Water	12.7 (14000/110000)	0.5 (75)	

Appendix 2. (cont.)

Ref.	Year	Place	Vehicle	Incubation median (days)	Attack rate % (no.)	Case fatality rate % (no.)
43:7	N. Carolina	1965	Potato salad	50.0 (244/488)	4.1 (10)	96
59:4	Montana	1966	Turkey	54.4 (31/57)	6.5 (2)	48†
63:5	Tennessee	1967	Potato salad	35.7 (215/602)		32
77:2	N. Carolina	1968	Icecream	89.5 (17/19)	0.0 (0)	
77:4	New Jersey	1968	Cafe	42.0 (245/583)	0.0 (0)	21‡
83:2	New York	1969	Spaghetti	50.0 (13/26)	15.4 (2)	34‡
102:2	N. Carolina	1970	Barbecued ham	74.7 (56/75)	32.1 (18)	
104:2	Missouri	1970	Icecream	100.0 (11/11)	0.0 (0)	
105:1§	Tennessee	1970	Barbecued pork	95.2 (40/42)	10.0 (4)	24‡
105:1§	Tennessee	1970	Barbecue	70.6 (12/17)	8.3 (1)	30
105:1§	Tennessee	1970	Turkey	87.3 (144/165)	2.8 (4)	
110:2	Michigan	1971	Smoked fish	75.7 (28/37)	10.7 (3)	
112:2	New Jersey	1971	Roast beef	61.1 (22/36)	27.3 (6)	
115:2	New Jersey	1972	Bakery cakes	12.5 (150/1200)	2.0 (3)	
118:2	Wisconsin	1972	Hamburger?	26.7 (20/75)	10.0 (2)	
116:3	Virginia	1972	Icecream	60.0 (45/75)	6.7 (3)	
<i>S. enteritidis</i>						
38:5	New Jersey	1965		50.0 (65/130)	4.6 (3)	
77:4	Ohio	1968	Icecream	100.0 (12/12)	8.3 (1)	
93:2	Alaska	1969	Whale	95.9 (93/97)		9
99:5	Columbia	1970	Picnic	48.1 (181/376)	1.1 (2)	28‡
101:4	Pennsylvania	1970	Salad	(130/)	23.1 (30)	18
102:2	Florida	1970	? Turkey	15.4 (139/900)	14.4 (2)	
103:2	Michigan	1970	Prison cafe	40.3 (353/876)	6.2 (22)	
104:2	Georgia	1970	Icecream	92.3 (12/13)	100.0 (12)	
104:2	Nebraska	1970	Roast meat	12.6 (252/2000)	6.8 (17)	
116:2	California	1972	Ham?	41.0 (41/100)	0.0 (0)	
116:2	Rhode Island	1972		5.8 (10/172)	20.0 (2)	
117:2	Oregon	1972		12.9 (17/132)	5.9 (1)	
123:2	Indiana	1974	Icecream	25.0 (25/100)	32.0 (8)	
<i>S. infantis</i>						
71:5	Kentucky	1968	Ham	67.3 (37/55)	27.0 (10)	20
85:2	Tennessee	1969	Smoked turkey	64.7 (11/17)	18.2 (2)	29‡
85:3	Texas	1969	Turkey	53.9 (28/52)	14.3 (4)	11
116:3	Kansas	1972	Icecream	100.0 (12/12)	91.7 (11)	
117:2	Illinois	1972	Bread dressing	12.7 (38/300)	26.3 (10)	
120:2	Oregon	1973	Roast beef	27.3 (123/450)	0.0 (0)	
123:2	Texas	1974		12.5 (50/400)	6.0 (3)	
<i>S. thompson</i>						
44:3	St Louis	1965	Icecream	92.3 (12/13)		18
95:2	New Orleans	1969	Church supper	99.5 (200/201)	25.4 (18)¶	13‡
99:1	Tennessee	1970	Barbecued pork	(303/)	17.8 (54)	54
102:2	New Jersey	1970		65.0 (130/200)	20.0 (26)	
112:2	Maine	1971	Chicken salad	51.5 (17/33)	0.0 (0)	29‡
113:2	Iowa	1971	Restaurant	43.2 (95/220)	23.2 (22)	
116:3	Pennsylvania	1972	Coconut cream	3.1 (31/1000)	38.7 (12)	
119:2	Florida	1973	Inflight food	14.8 (17/115)	11.8 (2)	
120:2	Los Angeles	1973	Custard pie	100.0 (23/23)	0.0 (0)	
120:2	Pennsylvania	1973	Roast beef	80.7 (25/31)	12.0 (3)	

* References give issue and page no.

† Incubation is 'average'.

‡ Incubation is mean.

§ Same restaurant.

¶ Information for 71 cases only.