Epidemiol. Infect. (1997), **119**, 15–23. Printed in the United Kingdom

Salmonella isolated from humans, animals and other sources in Canada, 1983–92

R. KHAKHRIA[1], D. WOODWARD[1], W. M. JOHNSON[1] AND C. POPPE[2]*

[1] *National Laboratory for Enteric Pathogens, Laboratory Centre for Disease Control, Health Canada, Tunney's Pasture, Ottawa, Ontario, Canada K1A 0L2*
[2] *Health of Animals Laboratory, Health Canada, 110 Stone Road West, Guelph, Ontario, Canada N1G 3W4*

(*Accepted 12 March 1997*)

SUMMARY

A total of 89 760 human and 22 551 non-human isolates of salmonella were serotyped in Canada during the period 1983–92. There were 2180 reported outbreaks associated with 10 065 cases during the 10-year period. The most common salmonella serovars isolated from human and non-human sources were *S. typhimurium* and *S. hadar*. The third and fourth most common serovars from human sources were *S. enteritidis* and *S. heidelberg*, respectively, and from non-human sources they were *S. heidelberg* and *S. infantis*. The number of *S. typhimurium* isolations from human and non-human sources showed a downward trend over the 10-year period. A total of 222 outbreaks of *S. typhimurium* associated with 1622 cases occurred. The *S. hadar* isolations from human and non-human sources reached a peak during the years 1987–90 and declined thereafter. The number of human isolates of *S. enteritidis* increased until 1985 and fluctuated at a level of 8·3–12·8% of all human isolates thereafter. Seventy-three outbreaks of *S. enteritidis* infection associated with 568 cases occurred. More than 50% of the *S. enteritidis* infections in humans were caused by phage type (PT) 8. During the review period, infections caused by PT4 were less common and were almost exclusively found in people who had travelled abroad. The annual isolation rates of *S. heidelberg* from human and non-human sources increased steadily during the period. Bacteriophage typing of serovars from outbreaks showed that contaminated food products of poultry and bovine origin were common sources of human infection. *Salmonella typhi* was identified as the cause of 43 small outbreaks affecting 116 persons.

INTRODUCTION

Salmonella is an important zoonotic pathogen in humans and animals. Infection of animals with various serovars of salmonella sometimes results in serious illness and always constitutes a vast reservoir for the disease in humans [1]. Monitoring the occurrence and the frequency of distribution of salmonella serovars from human, animal, food and other sources is important to detect possible outbreaks, to identify possible sources and to target prevention and control measures. Surveillance permits a better understanding of the epidemiology of salmonellosis. The fact that a number of the same serovars are found on lists of the 10 most commonly isolated serovars from human and animal sources underlines the importance of this relationship [2, 3]. Poultry, meat, milk, dairy products, person-to-person spread and pet-to-person exposures have caused many outbreaks [2–4]. *Salmonella typhimurium* has been the most frequently isolated serovar in Canada and the US and improperly pasteurized milk has caused the largest food-borne outbreaks in both countries [5, 6]. The present survey sets out the yearly isolation rates of salmonella from humans and animals in Canada

* Author for correspondence.

Table 1. *The ten most commonly isolated salmonella from human sources in Canada during the years 1983–92*

		1983		1984		1985		1986		1987		1988		1989		1990		1991		1992		Total	
Rank	Serovar	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	*S. typhimurium*	3485	43·1	6486	63·0	2574	36·1	2966	30·1	2704	25·3	1952	19·6	2129	24·3	2096	24·0	1822	20·3	1596	22·1	27810	31·0
2	*S. hadar*	402	5·0	282	2·7	419	5·9	1044	10·6	1679	15·7	1567	15·7	1556	17·8	1335	15·3	978	10·9	940	13·0	10202	11·4
3	*S. enteritidis*	265	3·3	283	2·7	602	8·4	929	9·4	888	8·3	914	9·2	798	9·1	1001	11·5	1119	12·5	925	12·8	7724	8·6
4	*S. heidelberg*	246	3·0	482	4·7	611	8·6	733	7·4	797	7·4	990	9·9	773	8·8	1131	12·9	1081	12·0	667	9·2	7511	8·4
5	*S. infantis*	590	7·3	387	3·8	476	6·7	417	4·2	582	5·4	320	3·2	297	3·4	339	3·9	219	2·4	157	2·2	3784	4·2
6	*S. thompson*	148	1·8	109	1·1	124	1·7	189	1·9	643	6·0	827	8·3	441	5·0	348	4·0	553	6·2	293	4·1	3675	4·1
7	*S. agona*	371	4·6	222	2·2	188	2·6	204	2·1	271	2·5	283	2·8	361	4·1	258	3·0	215	2·4	175	2·4	2548	2·8
8	*S. berta*	2	0·0	1	0·0	15	0·2	209	2·1	183	1·7	277	2·8	415	4·7	533	6·1	114	1·3	77	1·1	1826	2·0
9	*S. saint-paul*	161	2·0	203	2·0	143	2·0	196	2·0	151	1·4	204	2·0	202	2·3	212	2·4	97	1·1	86	1·2	1655	1·8
10	*S. newport*	221	2·7	128	1·2	142	2·0	193	2·0	95	0·9	125	1·3	130	1·5	167	1·9	215	2·4	111	1·5	1527	1·7
	Other serovars	2202	27·2	1720	16·7	1834	25·7	2781	28·2	2705	25·3	2498	25·1	1660	18·9	1322	15·1	2571	28·6	2205	30·5	21498	24·0
Total	All serovars	8093	100	10303	100	7128	100	9861	100	10698	100	9957	100	8762	100	8742	100	8984	100	7232	100	89760	100

Table 2. *The ten most commonly isolated salmonella from non-human sources in Canada during the years 1983–92*

		1983		1984		1985		1986		1987		1988		1989		1990		1991		1992		Total	
Rank	Serovar	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	*S. typhimurium*	616	24·3	455	22·6	285	17·9	339	14·1	354	15·9	389	12·1	233	20·0	121	4·4	76	3·8	213	8·0	3081	13·7
2	*S. hadar*	48	1·9	54	2·7	61	3·8	186	7·8	215	9·6	660	20·6	319	27·4	425	15·4	78	3·9	179	6·7	2225	9·9
3	*S. heidelberg*	62	2·4	102	5·1	121	7·6	164	6·8	175	7·9	273	8·5	114	9·8	248	9·0	380	19·2	512	19·1	2151	9·5
4	*S. infantis*	176	6·9	137	6·8	105	6·6	155	6·4	148	6·6	160	5·0	37	3·2	134	4·9	30	1·5	54	2·0	1136	5·0
5	*S. agona*	91	3·6	105	5·2	54	3·4	65	2·7	61	2·7	110	3·4	29	2·5	171	6·2	31	1·6	48	1·8	765	3·4
6	*S. schwarzengrund*	58	2·3	46	2·3	49	3·1	62	2·6	45	2·0	129	4·0	46	3·9	150	5·4	17	0·9	124	4·6	726	3·2
7	*S. anatum*	58	2·3	67	3·3	53	3·3	78	3·3	86	3·9	87	2·7	43	3·7	141	5·1	5	0·3	53	2·0	671	3·0
8	*S. enteritidis*	28	1·1	17	0·8	28	1·8	58	2·4	30	1·3	63	2·0	35	3·0	238	8·6	27	1·4	146	5·5	670	3·0
9	*S. senftenberg*	69	2·7	64	3·2	67	4·2	79	3·3	101	4·5	84	2·6	30	2·6	48	1·7	46	2·3	51	1·9	639	2·8
10	*S. muenster*	302	11·9	78	3·9	51	3·2	80	3·3	29	1·3	19	0·6	20	1·7	34	1·2	13	0·7	7	0·3	633	2·8
	Other serovars	1026	40·5	887	44·1	720	45·2	1134	47·3	985	44·2	1234	38·5	260	22·3	1047	38·0	1273	64·4	1288	48·1	9854	43·7
Total	All serovars	2534	100	2012	100	1594	100	2400	100	2229	100	3208	100	1166	100	2757	100	1976	100	2765	100	22551	100

during the period 1983–92. Annual frequency of isolation of serovars, outbreaks, numbers of cases per outbreak and phage types that linked the source to human illness, are reported.

MATERIALS AND METHODS

Isolates

During the 10-year period 1983–92 a total of 89760 human and 22551 non-human isolates of salmonella (Table 1) and/or results of serotyping were submitted by various Provincial Public Health Laboratories, Federal Laboratories and Veterinary Laboratories for serotyping and/or phage typing to the National Enteric Reference Centre, Laboratory Centre for Disease Control (LCDC), Ottawa, Canada [7]. Isolates serotyped and/or phage typed were designated strains.

Serotyping

Serological identification of *Salmonella* spp. was performed as described by Ewing [8]. The antigenic formulae of Le Minor and Popoff [9] were used to name the serovars.

Phage typing

The standard phage typing technique described by Anderson and Williams [10] was employed throughout. Strains that did not conform to any recognized phage type were considered atypical (AT). Strains which did not react with any of the typing phages were considered untypable (UT). The phage typing scheme for *S. typhimurium*, developed by Callow [11] and further extended by Anderson [12] and Anderson and colleagues [13], together with its phages and type strains, was obtained from the International Centre for Enteric Phage Typing (ICEPT), Central Public Health Laboratories, Colindale, UK. Phages used for the typing of the *S. typhimurium* phage types 771, 772, 811, 841 and 921 were isolated and propagated at the Laboratory Centre for Disease Control (LCDC), Ottawa, Canada [14]. The extended phage typing scheme for *S. typhi* [10, 15], *S. paratyphi* B [12], *S. enteritidis* [16], and the scheme for *S. hadar* [17] together with its phages and type strains were obtained from the ICEPT. Phage typing schemes for *S. heidelberg*, *S. infantis*, *S. newport*, and *S. thompson* were developed at the LCDC.

Table 3. *Number of salmonella serovars associated with outbreaks of food poisoning in Canada (1983–92)*

Year	Outbreaks (*n*)	Serovars (*n*)	Cases (*n*)
1983	69	20	641
1984	126	17	2680
1985	335	40	1056
1986	366	37	1216
1987	425	44	1237
1988	305	34	1126
1989	69	16	305
1990	52	12	279
1991	231	37	916
1992	202	25	609

Surveillance

The present summary is based on passive laboratory-based salmonella surveillance [7]. No distinction was made between symptomatic and asymptomatic infection or chronic carriage of human isolates. Cases of suspected salmonellosis without laboratory confirmation were not included. As noted by Hargrett-Bean and colleagues [18], such a surveillance system has inherent biases. Many factors, including intensity of surveillance, severity of illness, access to medical care, and association with a recognized outbreak, affect whether an infection will be reported. Infants, the elderly, and severely ill patients are all more likely to have stool cultures performed. Reporting of human salmonella infections is incomplete and the true incidence of human salmonellosis is substantially underestimated. However, these data permit broad comparisons, and identify trends, reservoirs and routes of transmission of salmonella serovars.

RESULTS

The numbers of salmonella strains that were isolated from human and non-human sources and serotyped in Canada during the 10-year period 1983–92 are shown in Tables 1 and 2, respectively. The annual human salmonella isolates serotyped varied between 7128 and 10698 strains per year and averaged 8976 strains. The non-human salmonella isolates serotyped annually varied between 1166 and 3208 strains with an average of 2255 strains. The 10 most frequently isolated serovars from human and non-human sources consisted of 68262 or 76·0% of all the isolates from human sources, and 12697 or 56·3% of all salmonella isolated from non-human sources. The two most

https://doi.org/10.1017/S0950268897007577 Published online by Cambridge University Press

Table 4. *Summary of salmonella outbreaks studied by phage typing in Canada* (*1983–92*)

	Outbreaks		Cases		
Serovar	*n*	%	*n*	%	Phage types
S. enteritidis	73	14·7	568	16·9	4, 4a, 8, 9a, 9b, 9c, 12, 13, 13a, 14b, 22, 28
S. hadar	46	9·3	421	12·5	2, 4, 10, 11, 14, 21, 58
*S. heidelberg**	35	7·1	205	6·1	Provisional: 1, 6, 7, 8, 10, 12
*S. infantis**	17	3·4	124	3·7	3, 4, 7, 9, 10, 11, 13
*S. newport**	13	2·6	84	2·5	6, 10, 13, 14, ATYPICAL, UNTYPABLE
S. paratyphi-B & *S. java*	21	4·2	60	1·8	1 var 3, 1 var 5, 3a var 4, Battersea, Taunton, Worksop, UNTYPABLE
*S. thompson**	26	5·2	159	4·7	1, 3, 6, 12, 21, 25, 26, ATYPICAL
S. typhi	43	8·7	116	3·5	B1, B2, B3, D2, D6, E1, E2, E4, F4, K1, O, T, 28, 38, 46, DVS, I+IV
S. typhimurium	222	44·8	1622	48·3	1, 2, 4, 10, 12, 14, 22, 35, 45, 49, 66, 67, 69, 74, 82, 104, 122, 132, 133, 144, 160, 164, 165, 193, 194, 195, 199, 204, 771†, 772†, 811†, 841†, 921†, ATYPICAL
Total	496	100	3359	100	

* Phage typing schemes for these serovars were developed at the Laboratory Centre for Disease Control (LCDC).
† LCDC designation of new types.

common salmonella serovars from human and non-human sources in Canada during the years 1983–92 were the same, namely *S. typhimurium* and *S. hadar*, respectively. The annual rate of serotyped *S. typhimurium* isolates from human and non-human sources showed a continuing long-term decline over the study period. The annual isolation rates of *S. hadar* from both human and non-human sources peaked during the years 1987–90 and have since declined (Tables 1 and 2). The annual human isolation rate reached a high of 15·3–17·8% of all isolates during the years 1987–90 (Table 1).

The third and fourth most common serovars from human sources were *S. enteritidis* and *S. heidelberg* respectively; from non-human sources they were *S. heidelberg* and *S. infantis* (Tables 1 and 2). The annual isolation rates of *S. enteritidis* from human sources increased considerably during the 10-year period (Table 1). In contrast, *S. enteritidis* ranked as the eighth most common serovar isolated from animal, food and other non-human sources during the 10-year period and increased isolation rates were found only in 1990 and 1992 (Table 2). The annual isolation rates of *S. heidelberg* from human and non-human sources increased gradually over the 10-year period (Tables 1 and 2).

The numbers of annual isolations of *S. infantis* from both human and non-human sources declined gradually over the 10-year period (Tables 1 and 2). The isolation rates of *S. thompson* from human sources increased gradually reaching a peak in 1988 and declining subsequently (Table 1). *Salmonella berta* was rarely isolated from human sources in 1983 and 1984, but the annual isolation rates rose to 533 (6·1%) in 1990 and declined in the years thereafter (Table 1). Among the isolates from non-human sources, *S. muenster* decreased from 302 or 11·9% in 1983 to only 7 isolates or 0·3% in 1992 (Table 2).

The number of outbreaks of food poisoning, the number of serovars identified during the outbreaks, and the numbers of cases affected during the outbreaks are tabulated on an annual basis for the 10-

https://doi.org/10.1017/S0950268897007577 Published online by Cambridge University Press

Table 5. *Frequency of phage types of* Salmonella typhimurium *from human and non-human sources in Canada* (*1983–92*)

Phage type	Source: Human *n*	%	Non-human *n*	%	Total *n*	%
1	43	1·5	6	0·7	49	1·3
2	27	0·9	56	6·7	83	2·2
10	1335	45·3	109	13·0	1444	38·1
14	22	0·7	25	3·0	47	1·2
22	60	2·0	6	0·7	66	1·7
35	4	0·1	10	1·2	14	0·4
40	1	0·0	13	1·6	14	0·4
49	12	0·4	19	2·3	31	0·8
66	220	7·5	20	2·4	240	6·3
69	9	0·3	11	1·3	20	0·5
93	6	0·2	9	1·1	15	0·4
104	126	4·3	93	11·1	219	5·8
108	—	—	17	2·0	17	0·4
160	9	0·3	23	2·7	32	0·8
164	110	3·7	37	4·4	147	3·9
193	8	0·3	15	1·8	23	0·6
204	86	2·9	27	3·2	113	3·0
771*	69	2·3	34	4·1	103	2·7
772*	73	2·5	81	9·7	154	4·1
811*	348	11·8	48	5·7	396	10·5
841*	62	2·1	9	1·1	71	1·9
Atypical	116	3·9	56	6·7	172	4·5
Untypable	89	3·0	23	2·7	112	3·0
Other†	114	3·9	90	10·8	204	5·4
Total	2949	100	837	100	3786	100

* LCDC designations of new phage types.
† Fifty-two other phage types were isolated from humans and/or non-human sources with a frequency of less than 1%.

year period in Table 3. The numbers of outbreaks listed for 1983, 1989 and 1990 were lower than in other years because some of the provincial laboratories did not report all outbreaks.

During the 10-year period, *S. typhimurium* strains belonging to as many as 33 different phage types were isolated from 1622 cases in 222 outbreaks (Table 4). A total of 73 outbreaks of *S. enteritidis* affecting 568 cases was observed. The *S. enteritidis* strains that were isolated from the outbreaks belonged to 12 different phage types. There were 35 reported outbreaks of *S. heidelberg* infection that affected 205 people. The isolates belonged to six phage types of the provisional phage typing scheme. Forty-six outbreaks of *S. hadar* infection affecting 421 humans occurred. The *S. hadar* isolates belonged to seven phage types; more than

Table 6. *Frequency of phage types of* Salmonella enteritidis *from human and non-human sources in Canada* (*1983–92*)

Phage type	Source: Human *n*	%	Non-human *n*	%	Total *n*	%
1	21	1·3	—	—	21	1·2
4	294	18·4	6	5·0	300	17·5
4a	17	1·1	—	—	17	1·0
8	835	52·3	65	54·6	900	52·5
9b	24	1·5	3	2·5	27	1·6
13	178	11·2	18	15·1	196	11·4
13a	83	5·2	5	4·2	88	5·1
14b	23	1·4	—	—	23	1·3
22	13	0·8	5	4·2	18	1·0
28	18	1·1	—	—	18	1·0
911*	9	0·6	10	8·4	19	1·1
Atypical	16	1·0	2	1·7	18	1·0
Other†	65	4·1	5	4·2	70	4·1
Total	1596	100	119	100	1715	100

* LCDC designations of new phage types.
† Twenty-one other phage types were isolated from human and/or non-human sources with a frequency of less than 1%.

75% were PT2 (data not shown). Seventeen outbreaks of *S. infantis* infection affecting 124 persons occurred; the strains belonged to seven phage types of the provisional phage typing scheme. There were 26 mostly small family outbreaks of *S. thompson* infection affecting 159 persons; the strains belonged to the seven different phage types of the provisional phage typing scheme.

The phage types of *S. typhimurium* strains isolated from human and non-human sources are shown in Table 5. Phage type 10 was the most common among human and non-human sources. The frequency of phage types of *S. enteritidis* strains isolated from human and non-human sources over the 10-year period is shown in Table 6. Phage type 8 was the most common among the *S. enteritidis* strains that were phage typed from human sources, followed by PT4, PT13 and PT13a, whereas among those from animal and other non-human sources PT8 was commonest followed by PT13. The isolation rates of *S. enteritidis* PT4 from human sources increased gradually during the period 1987–92 and PT4 became the most frequent *S. enteritidis* phage type in 1992. *Salmonella enteritidis* PT4 was seldom isolated from poultry or other non-human sources. During the review period, there were

Table 7. Salmonella typhi *outbreaks in Canada* (*1983–92*)

Phage type	Outbreaks *n*	Outbreaks %	Cases *n*	Cases %	Outbreak type	Source of travel history
B1	5	11·5	14	12·1	Family (4)*	
					Community (1)	Philippines (1)
B2	1	2·3	2	1·7	Family (1)	
B3	2	4·7	5	4·3	Family (2)	India (1)
D2	1	2·3	2	1·7	Family (1)	
D6	1	2·3	2	1·7	Family (1)	
E1	9	20·9	35	30·2	Family (5)	
					Community (4)	Shellfish (1)
E2	3	7·0	9	7·8	Family (2)	Philippines (1)
					Community (1)	
E4	1	2·3	3	2·6	Family (1)	
F4	1	2·3	3	2·6	Community (1)	Iran (1)
K1	2	4·7	3	2·6	Family (2)	
O	1	2·3	2	1·7	Family (1)	
T	3	7·0	9	7·8	Family (2)	India (1)
					Community (1)	Punjab (1)
28	1	2·3	3	2·6	Family (1)	
38	1	2·3	2	1·7	Family (1)	
46	1	2·3	2	1·7	Community (1)	Pakistan (1)
DVS	5	11·6	10	8·6	Family (3)	
					Community (2)	
I+IV	5	11·6	10	8·6	Family (3)	India (1)
						Vietnam (1)
					Community (2)	Bangladesh (1)
Total	43	100	116	100		

* No. of outbreaks in parentheses.

43 outbreaks of human disease caused by *S. typhi* affecting 116 cases (Table 7). The isolates belonged to 17 different phage types.

DISCUSSION

The decline in the isolation rate of *S. typhimurium* from humans continued during the review period and was similar to, but not as pronounced as, that which occurred in many European countries and the US [3, 19–21]. *Salmonella typhimurium* was the commonest serovar isolated from cattle and was also commonly isolated from swine [1, 7, 22]. The decline of *S. typhimurium* isolations from humans may have been related to lower consumption of beef and pork and increased consumption of poultry [23], and was undoubtedly also influenced by the declining prevalence of *S. typhimurium* in poultry and poultry products during the last decades [22, 24–28]. However, *S. typhimurium* was still the commonest serovar isolated from humans in Canada in 1992. The cause of many of these outbreaks of *S. typhimurium* infections was not identified or could not be determined, but in a small number of outbreaks a variety of sources were identified. Incriminated foods included chicken, lamb chops, raw egg whites, cooked turkey, and cheddar cheese [7, 29–32]. Other outbreaks were associated with a variety of animals including a garter snake, cats, and calves [7, 33, 34]. Phage type 10 replaced PT49 as the most common PT from human and non-human sources. It was isolated from cheddar cheese and consumers thereof during a major Canadian food-borne outbreak [5, 14, 31].

Salmonella hadar infections in humans were often associated with the consumption of chickens or turkeys. In 1973 and 1974, *S. hadar* became established in flocks of the largest turkey breeder in Britain, spread to numerous rearing units throughout the country, and later also became prevalent in broiler chicken flocks [35, 36]. This spread was accompanied by a rapidly increasing prevalence in the human population [35]. After importation of turkey breeder stock from England to Canada and the US [37], a rapid increase in isolations of *S. hadar* from humans

https://doi.org/10.1017/S0950268897007577 Published online by Cambridge University Press

in Canada and the US associated with consumption of turkeys and broilers ensued [36, 38, 39]. In a Canada-wide survey carried out in 1990 *S. hadar* was isolated from 33% of broiler flocks and was the most common serovar in these flocks [27]. Also *S. hadar* ranked as the second most commonly isolated serovar from turkey flocks [28]. The reasons for the recent decline in the annual isolation rate of *S. hadar* from humans are unknown. A decline in the occurrence of *S. hadar* in broiler and turkey breeder flocks would probably result in lower infection rates in rearing flocks [40] and subsequent lower contamination rates of fresh broiler and turkey carcasses.

The annual isolation rates of *S. enteritidis* from human sources varied between 3·7 and 8·7% of all salmonella isolates during the period 1976–82 [41], but increased considerably during the present review period. The majority of the isolates from non-human sources were from layer and broiler flocks [26, 27, 42], but *S. enteritidis* strains were rarely isolated from turkey flocks or from other animals [28, 41–44]. Large outbreaks of *S. enteritidis* infection in humans have occurred only rarely in Canada during this period. A notable exception was an outbreak of 95 cases of infection with *S. enteritidis* PT13 which occurred among patients and staff of a regional hospital in Owen Sound, Ontario. A difficult-to-clean vertical mixer used to blend raw shelled eggs, minced ham and sandwich fillings, was the most likely vehicle of transmission [45].

Salmonella enteritidis PT4 was increasingly isolated from human sources during the period 1987–92 but was seldom isolated from poultry or other non-human sources [41–43]. The difference between the increased isolation rates of *S. enteritidis* PT4 from human sources compared with those from non-human sources may be explained by the observation that almost all of the human isolates of *S. enteritidis* PT4 were acquired while travelling abroad [46] and the finding that the rapid rise of *S. enteritidis* in the European countries and South America was primarily due to a dramatic rise in the occurrence of *S. enteritidis* PT4 [19, 20]. One of the main reasons why the numbers of *S. enteritidis* PT4 infections have not increased in the human population in Canada to such an extent as in the European countries may be related to its absence in breeder flocks and consequently its absence in layer flocks [26, 47]. *Salmonella enteritidis* PT4 was isolated only once from the environment of laying hens [42]. Another reason may be the common practice in Canada of refrigerating table eggs from the producer to the consumer. No growth of *S. enteritidis* strains of different phage types occurred when eggs were stored at 8 °C [48].

There is evidence that may link *S. heidelberg* in laying hens and eggs with its occurrence in humans. *Salmonella heidelberg* was the commonest serovar isolated from layer flocks and the second most commonly isolated serovar from turkey flocks in nation-wide Canadian surveys conducted in 1989 and 1990 [26, 28, 47], and also the commonest serovar isolated from the ovaries of spent hens during a survey in the US [49]. Infection of ovaries and oviducts with salmonellas may result in the contamination of eggs [50, 51]. An egg-associated outbreak of *S. heidelberg* infection affected 91 of a total of about 1000 persons who attended a convention in New Mexico and consumed eggs that appeared to be 'runny' and insufficiently cooked [52]. Despite its frequent isolation from laying hens [26, 47, 49] and their environment [26], *S. heidelberg* did not become the most common serovar isolated from humans. One of the reasons may be that *S. typhimurium* and *S. enteritidis* are more pathogenic for susceptible human hosts (infants, the elderly, and those compromised immunologically) than *S. heidelberg* [53, 54].

In one outbreak at a home for the elderly, 44 symptomatic and 71 asymptomatic cases of *S. infantis* occurred. The source of the outbreak was not identified, but food preparation practices were sub-optimal [7, 55]. Human infection with *S. muenster* was associated with the drinking of raw milk by farm families [56]. Outbreaks of *S. muenster* infection in dairy cattle in Ontario were characterized by diarrhoea, fever and occasional abortion [56].

The *S. typhi* outbreaks were mainly family outbreaks (contact-cases) and were often limited to two or three persons per outbreak. Almost all of the *S. typhi* strains were isolated from visitors and immigrants to Canada and from patients who had travelled to countries where *S. typhi* contamination and infection occur more frequently than in Canada. A single indigenous case occurred in New Brunswick in 1986 associated with the consumption of mussels. *Salmonella typhi* Vi positive phage type A was isolated [57].

In summary, during the 1983–92 period, *Salmonella enteritidis* did not become the most frequently isolated salmonella serovar in Canada as happened in many other countries. The isolation rates of the common salmonella serovars from human sources (*S. typhimurium*, *S. hadar* and *S. heidelberg*) generally showed

https://doi.org/10.1017/S0950268897007577 Published online by Cambridge University Press

the same trends as those isolated from animal sources in magnitude and annual frequencies. Bacteriophage typing of serovars from outbreaks showed that contaminated food products of poultry and bovine origin were common sources of human infection in Canada.

ACKNOWLEDGEMENTS

We thank Mr H. Lior, former Chief of the National Laboratory for Enteric Pathogens, Bureau of Microbiology, LCDC, Ottawa, for his contributions. We also thank Ms M. Bell, Ms D. Duck, and Mr W. H. B. Demczuk for their excellent technical assistance in serotyping and phage typing of the salmonella isolates. We express our thanks to the Directors of the Provincial Public Health Laboratories, Federal Laboratories and Veterinary Laboratories for submission of cultures and data.

REFERENCES

1. Clarke RC, Gyles CL. *Salmonella*. In: Gyles CL, Thoen CO, eds. Pathogenesis of bacterial infections in animals, 2nd ed. Ames: Iowa State University Press, 1993: 133–53.
2. Gangarosa EJ. What have we learned from 15 years of *Salmonella* surveillance? In: Proceedings of the National Salmonellosis Seminar. Washington, 1978.
3. Lior H, Khakhria R. Prevalence of *Salmonella* serotypes and phage types in Canada (1973–1982). In: Snoeyenbos GH, ed. Proceedings of the International Symposium on *Salmonella*. New Orleans: American Association of Avian Pathologists, Inc., 1985: 332–3.
4. Todd ECD. Foodborne and waterborne disease in Canada – 1978 annual summary. J Food Protect 1985; **48**: 990–6.
5. Bezanson GS, Khakhria R, Duck D, Lior H. Molecular analysis confirms food source and simultaneous involvement of two distinct but related subgroups of *Salmonella typhimurium* bacteriophage type 10 in major interprovincial *Salmonella* outbreak. Appl Environ Microbiol 1985; **50**: 1279–84.
6. Ryan CA, Nickels MK, Hargrett-Bean NT, et al. Massive outbreak of antimicrobial-resistant salmonellosis traced to pasteurized milk. JAMA 1987; **258**: 3269–74.
7. Lior H, Khakhria R. Salmonellae, Shigellae, enteropathogenic *E. coli*, Campylobacters and *Aeromonas* identified in Canada. Monthly Reports, 1983–1992. National Enteric Reference Centre, Laboratory Centre for Disease Control, Ottawa, Canada.
8. Ewing WH. Serologic identification of *Salmonella*. In: Ewing WH, ed. Edwards and Ewing's Identification of *Enterobacteriaceae*, 4th ed. New York: Elsevier Science Publishing Co., Inc., 1986: 201–38.
9. Le Minor L, Popoff MY. Antigenic formulas of the *Salmonella* serovars, 5th ed. Paris: WHO Collaborating Centre for Reference and Research on *Salmonella*, 1992.
10. Anderson ES, Williams REO. Bacteriophage typing of enteric pathogens and staphylococci and its use in epidemiology. J Clin Pathol 1956; **9**: 94–114.
11. Callow BR. A new phage typing scheme for *Salmonella typhimurium*. J Hyg 1959; **57**: 346–59.
12. Anderson ES. The phagetyping of *Salmonella* other than *S. typhi*. In: Van Oye E, ed. The world problem of salmonellosis. The Hague, The Netherlands: Dr W. Junk Publishers, 1964: 89–100.
13. Anderson ES, Ward LR, de Saxe MJ, de Sa JDH. Bacteriophage-typing designations of *Salmonella typhimurium*. J Hyg 1977; **78**: 297–300.
14. Khakhria R, Lior H. Distribution of phagovars of *Salmonella typhimurium* in Canada (1969–1976). Zbl Bakt Hyg I, Abt Orig A 1980; **248**: 50–63.
15. Anonymous. The geographical distribution of *Salmonella typhi* and *Salmonella paratyphi* A and B phage types during the period 1 January 1970 to 31 December 1973. A report of the International Federation for Enteric Phage-Typing (IFEPT). J Hyg 1982; **88**: 231–4.
16. Ward LR, de Sa JDH, Rowe B. A phage-typing scheme for *Salmonella enteritidis*. Epidemiol Infect 1987; **99**: 291–4.
17. De Sa JDH, Ward LR, Rowe B. A scheme for the phage typing of *Salmonella hadar*. FEMS Microbiol Lett 1980; **9**: 175–7.
18. Hargrett-Bean NT, Pavia AT, Tauxe RV. *Salmonella* isolates from humans in the United States, 1984–1986. MMWR 1988; **37**: 25–31.
19. Rodrigue DC, Tauxe RV, Rowe B. International increase in *Salmonella enteritidis*: a new pandemic? Epidemiol Infect 1990; **105**: 21–7.
20. Hof, H. Epidemiologie der Salmonellose im Wandel. Dtsch Med Wschr 1991; **116**: 545–7.
21. Hargrett-Bean N, Potter ME. *Salmonella* serotypes from human sources, January 1992 through December 1992. In: Proceedings of the 98th Annual Meeting of the United States Animal Health Association. Richmond, VA: Carter Printing, 1994: 439–42.
22. Ferris KE, Miller DA. *Salmonella* serotypes from animals and related sources reported during July 1990–June 1991. In: Proceedings of the 95th Annual Meeting of the United States Animal Health Association. Richmond, VA: Carter Printing, 1991: 440–54.
23. Reilly WJ, Forbes GI, Sharp JCM, Oboegbulem SI, Collier PW, Paterson GM. Poultry-borne salmonellosis in Scotland. Epidemiol Infect 1988; **101**: 115–22.
24. Williams JE, Dillard LH, Hall GO. The penetration patterns of *Salmonella typhimurium* through the outer structures of chicken eggs. Avian Dis 1968; **12**: 445–66.
25. McIlroy SG, McCracken RM. The current status of the *Salmonella enteritidis* control programme in the United Kingdom. In: Proceedings of the 94th Annual Meeting of the United States Animal Health Association. Richmond, VA: Carter Printing, 1990: 450–62.

26. Poppe C, Irwin RJ, Forsberg CM, Clarke RC, Oggel J. The prevalence of *Salmonella enteritidis* and other *Salmonella* spp. among Canadian registered commercial layer flocks. Epidemiol Infect 1991; **106**: 259–70.
27. Poppe C, Irwin RJ, Messier S, Finley GG, Oggel J. The prevalence of *Salmonella enteritidis* and other *Salmonella* spp. among Canadian registered commercial chicken broiler flocks. Epidemiol Infect 1991; **107**: 201–11.
28. Irwin RJ, Poppe C, Messier S, Finley GG, Oggel J. A national survey to estimate the prevalence of *Salmonella* species among Canadian registered commercial turkey flocks. Can J Vet Res 1994; **54**: 263–7.
29. Rochard C, Bragg M, Jones S, Pringle T. *Salmonella* outbreak at a facility for the developmentally handicapped – Ontario. Can Dis Weekly Rep 1985; **11**: 182–4.
30. Lior H, Clark D, Butler R. Salmonellosis – Atlantic Provinces. Can Dis Weekly Rep 1984; **10**: 101.
31. D'Aoust J-Y, Warburton DW, Sewell AM. *Salmonella typhimurium* phage type 10 from cheddar cheese implicated in a major Canadian food borne outbreak. J Food Protect 1985; **48**: 1062–6.
32. Ogilvie TH. The persistent isolation of *Salmonella typhimurium* from the mammary gland of a cow. Can Vet J 1986; **27**: 329–31.
33. Noseworthy G, Severs D. *Salmonella* infections from reptiles – Newfoundland. Can Dis Weekly Rep 1985; **11**: 117.
34. Schoonderwoerd M, Lewis I, Lundberg W. *Salmonella typhimurium* in Alberta livestock – 1988. In: Proceedings of the 39th Conference of Canadian Laboratory Workers in Animal Diseases. Ottawa, 1989.
35. Rowe B, Hall MLM, Ward LR, de Sa JDH. Epidemic spread of *Salmonella hadar* in England and Wales. BMJ 1980; **2**: 1065–6.
36. Rowe B, Lior H, Acres S. *Salmonella hadar* – England and Wales. MMWR 1980; **29**: 506–13.
37. Rigby CE, Pettit JR, Papp-Vid G, Spencer JL, Willis NG. The isolation of salmonellae, Newcastle disease virus and other infectious agents from quarantined imported birds in Canada. Can J Comp Med 1981; **45**: 366–70.
38. Reynolds PJ, Tudor V, Zoltan T, Black W. An outbreak of salmonellosis – British Columbia. Can Dis Wkly Rep 1980; **6**: 85–8.
39. Finlayson M. A *Salmonella* survey of take-out fried chicken establishments carried out during 1979 – Alberta. Can Dis Wkly Rep 1980; **6**: 73–9.
40. McIlroy SG, McCracken RM, Neill SD, O'Brien JJ. Control, prevention and eradication of *Salmonella enteritidis* infection in broiler and broiler breeder flocks. Vet Rec 1989; **125**: 545–8.
41. Khakhria R, Duck D, Lior H. Distribution of *Salmonella enteritidis* phage types in Canada. Epidemiol Infect 1991; **106**: 25–32.
42. Poppe C, McFadden KA, Brouwer AM, Demczuk W. Characterization of *Salmonella enteritidis* strains. Can J Vet Res 1993; **57**: 176–84.
43. Poppe C. *Salmonella enteritidis* in Canada. Int J Food Microbiol 1994; **21**: 1–5.
44. Wood JD, Chalmers GA, Fenton RA, Pritchard J, Schoonderwoerd M, Lichtenberger WL. Persistent shedding of *Salmonella enteritidis* from the udder of a cow. Can Vet J 1991; **32**: 738–41.
45. Anonymous. Hospital outbreak of *Salmonella enteritidis* infection: Ontario. Can Common Dis Rep 1992; **18**: 57–60.
46. Khakhria R, Johnson W, Lior H. Canada's most common *Salmonella* serotypes and *Salmonella enteritidis* phage types (1992–1993). Safety Watch 1994; **33**: 4.
47. Poppe C, Johnson RP, Forsberg CM, Irwin RJ. *Salmonella enteritidis* and other *Salmonella* in laying hens and eggs from flocks with *Salmonella* in their environment. Can J Vet Res 1992; **56**: 226–32.
48. Humphrey TJ. Growth of salmonellas in intact shell eggs: influence of storing temperature. Vet Rec 1990; **126**: 292.
49. Barnhart HM, Dreesen DW, Bastien R, Pancorbo OC. Prevalence of *Salmonella enteritidis* and other serovars in ovaries of layer hens at time of slaughter. J Food Protect 1991; **54**: 488–91.
50. Snoeyenbos GH, Smyser CF, VanRoekel H. *Salmonella* infections in the ovary and peritoneum of chickens. Avian Dis 1969; **13**: 668–70.
51. Timoney JF, Shivaprasad HL, Baker RC, Rowe B. Egg transmission after infection of hens with *Salmonella enteritidis* phage type 4. Vet Rec 1989; **125**: 600–1.
52. Weisse P, Libbey E, Nims L, et al. *Salmonella heidelberg* outbreak at a convention – New Mexico. MMWR 1986; **35**: 91.
53. Levine WC, Buehler JW, Bean NH, Tauxe RV. Epidemiology of nontyphoidal *Salmonella* bacteraemia during the human immunodeficiency virus epidemic. J Infect Dis 1991; **164**: 81–7.
54. Telzak EE, Budnick LD, Zweig Greenberg MS, et al. A nosocomial outbreak of *Salmonella enteritidis* infection due to the consumption of raw eggs. New Engl J Med 1990; **323**: 394–7.
55. Grey JK, Devitt B, Robinson H, Connor A, Turner R. *Salmonella* in a home for the aged, Oshawa, Ontario. Ont Dis Surv Rep 1984; **5**: 1–4.
56. Styliadis S, Barnum D. *Salmonella muenster* infection in man and animals in the province of Ontario. In: Snoeyenbos GH, ed. Proceedings of the International Symposium on *Salmonella*. New Orleans: American Association of Avian Pathologists, Inc., 1985: 200–8.
57. Farley JD, Waters D, Gilchrist FI, Richard G, Edgett T, Bone H. Indigenous typhoid – New Brunswick. Can Dis Wkly Rep 1986; **12**: 121–2.