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Salmonellae in abattoirs, butchers' shops and home-produced meat, and their relation to human infection

Report of a Working Party of the PUBLIC HEALTH LABORATORY SERVICE*

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INTRODUCTION

Meat was first implicated as a source of human salmonella infection by Gaertner in 1888. Since then there have been many improvements in the handling, inspection and hygiene of meat but even today salmonella infection may often be traced to infected or contaminated meat. Meat and its products were the commonest known vehicle of salmonella infection in England and Wales between 1949 and 1961 (Galbraith, 1961; Reports, 1961, 1962*a*). The part played by home-produced meat in outbreaks in Great Britain is not known, although it has been proved to be the vehicle of infection in some of them. Some outbreaks have been related to a local abattoir (Camps, 1947) whereas others, such as those recorded by Anderson, Galbraith & Taylor (1961) and Galbraith, Archer & Tee (1961), have been more widespread. The source of infection in smaller outbreaks or in sporadic cases is often not found, but McDonagh & Smith (1958) in Bradford, and Harvey & Phillips (1961) in Cardiff noted a close relation between the types of salmonellae isolated from local abattoirs and from human cases in their districts. Anderson (1960) compared the phage-type distribution of strains of *Salmonella typhimurium* from human infections with that of strains from animals; of the six types encountered most frequently in man and animals, five were common to both groups.

A Working Party of the Public Health Laboratory Service was formed in 1960 to ascertain the degree of infection of meat and meat products from the abattoir, and the route of infection through the food factory and the butcher's shop, to the public. This report of the Working Party records the results of a study of the incidence of salmonellae in thirty-two abattoirs in 1961 and 1962, and of the relation of these findings to human salmonella infection. The distribution of the laboratories which participated in the work is shown in Fig. 1.

* The Working Party included the following members of the Public Health Laboratory Service: Dr H. G. M. Smith (Bradford, *Chairman*), Dr E. S. Anderson (Colindale), Dr G. T. Cook (Guildford), Dr D. G. Davies (Carlisle), Dr J. M. S. Dixon (Ipswich, *Secretary*), Dr N. S. Galbraith (Colindale, until June 1963), Dr R. W. S. Harvey (Cardiff), Dr R. J. Henderson (Worcester), Dr Betty C. Hobbs (Colindale), Dr M. H. Hughes (Winchester), Dr C. H. Jellard (Plymouth), Dr G. J. G. King (Bournemouth), Dr W. F. Lane (Bedford), Dr G. B. Ludlam (Leeds), Dr J. H. McCoy (Hull), Dr D. J. H. Payne (Northallerton), Dr L. Robertson (Preston), Dr J. A. Rycroft (Southend), Dr A. J. Kingsley Smith (Conway), Dr Joan Taylor (Colindale), Dr G. H. Tee (Dorchester), Dr P. J. Wormald (Salisbury) and Mrs E. Vernon (Colindale, from July 1963).

Requests for reprints should be addressed to Dr J. M. S. Dixon, Public Health Laboratory, Woodbridge Road East, Ipswich, Suffolk.

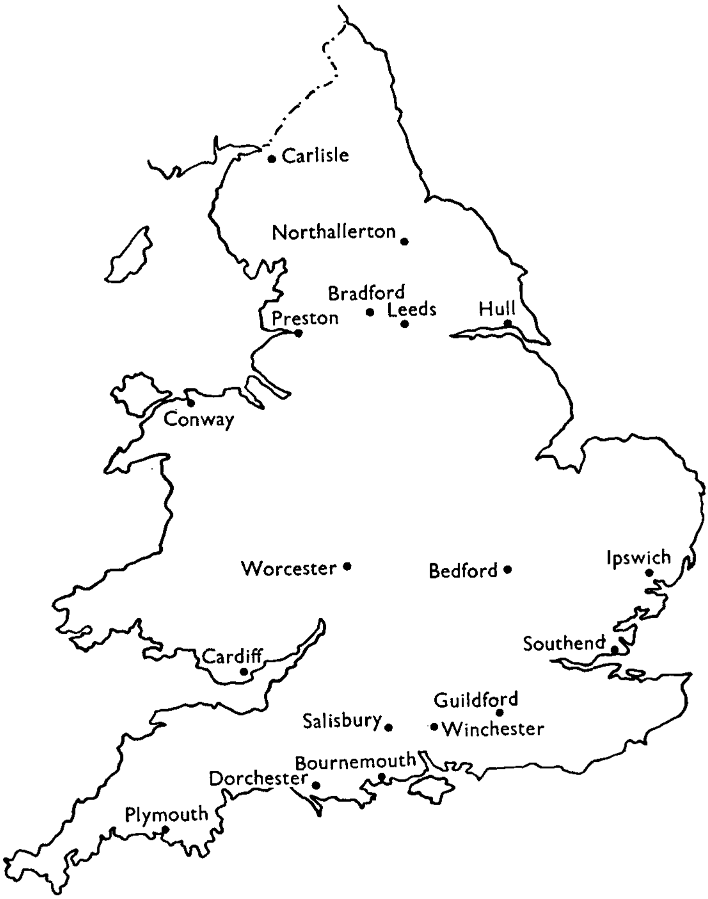

Fig. 1. *Distribution of laboratories which participated in the field work.*

MATERIALS AND METHODS

The abattoir

(1) Abattoir drains were examined by Moore's gauze-swab technique (Moore, 1948). Swabs were generally left in position for at least 2 days and often for a longer period.

(2) Tissue specimens were collected from animals immediately after slaughter at the abattoir and placed in sterile containers for transport to the laboratory. The tissues selected were mainly spleen, liver and mesenteric lymph nodes. Other material, such as caecal swabs and faeces, was also examined but such specimens were too few to warrant inclusion in this report.

Retail butchers' shops

Gauze swabs from drains or gulleys of retail butchers' shops and markets were examined by the swab method as for abattoir drains.

Meat and meat products

Materials examined included pork and beef sausages, raw meat, raw pie meat, potted meat and minced meat.

Laboratory technique

Laboratory methods were not standardized and each member used the methods for isolation of salmonellae with which he was most familiar. Selenite F broth was used as an enrichment medium except in one laboratory where tetrathionate was used. Enrichment media were incubated at either 37 or 43° C. and subcultured daily for 2, 3 or 4 days. Most laboratories used a modification of Wilson and Blair's bismuth sulphite agar for subculture and many used additional selective media such as deoxycholate-citrate agar or brilliant-green MacConkey agar. The selective media were examined after varying times of incubation at 37° C. and colonies suspected of being salmonellae were examined in the usual manner by serological and biochemical tests. The phage-typing of *S. typhimurium* was carried out by the Enteric Reference Laboratory and the serotyping of the majority of other salmonellae by the Salmonella Reference Laboratory.

RESULTS

Abattoir investigation

(*a*) *Drain swabs*

Drain swabs from thirty-two slaughterhouses were examined. Twenty-eight of the abattoirs killed cattle, sheep and pigs; two killed only pigs; one, cattle and sheep; and another, pigs and sheep. Details of the animals killed and of the results of examination of drain swabs for salmonellae from each of these abattoirs are shown in Table 1. Drain swabs were examined regularly during 1961–62 from twenty-six abattoirs, from one abattoir during 1961 only, and from five abattoirs during 1962 only. Salmonellae were isolated from 930 (20·7 %) of 4496 swabs examined during the investigation. From two abattoirs in which only pigs were killed, isolations of salmonellae were made from 57 and 91 % of drain swabs examined. From abattoirs in which pigs, cattle and sheep were killed, isolations of salmonellae ranged from 73 % of swabs examined to zero.

Factors which may have influenced the isolations of salmonellae from drain swabs from the twenty-four abattoirs which killed pigs, cattle and sheep (numbers 1–24 in Table 1), and which were examined regularly during both 1961 and 1962, have been analysed. To study the influence of the numbers of animals killed abattoirs were divided into three groups of equal size according to the annual slaughter rate. Table 2 shows the number of animals killed in 1961 and 1962 and the percentage of swabs from which salmonellae were isolated; no correlation is evident. In each group there were considerable differences in salmonella isolations between abattoirs killing similar numbers of animals, as may be seen in Table 1.

The figures in Table 1 also suggest that the proportion of different animal species killed is of importance. To study this suggestion the twenty-four abattoirs were

Table 1. *Results of the examination of abattoir drain swabs during* 1961 *and* 1962

			Animals slaughtered in a year				Drain swabs, 1961		Drain swabs, 1962		Drain swabs, 1961–62
No.	Laboratory	Abattoir	Total	Pigs (%)	Cattle (%)	Sheep (%)	Positive/examined	Positive (%)	Positive/examined	Positive (%)	Positive (%)
1	Ipswich	Beccles, 1	13,347	6	61	33	63/78	81	47/72	65	73
2	Winchester	Winchester	31,000	55	33	11	70/106	66	15/20	75	67
3	Preston	Walton le Dale	16,203	0	59	41	42/77	55	22/84	26	40
4	Bournemouth	Wimborne	61,704	37	35	28	70/175	40	67/209	32	36
5	Cardiff	Barry	28,242	16	14	70	9/51	18	36/85	42	33
6	Ipswich	Ipswich	21,500	59	30	11	8/20	40	7/29	24	31
7	Ipswich	Beccles, 2	1,464	47	20	33	21/69	30	13/88	15	22
8	Bedford	Bedford, 1	15,200	30	18	52	4/47	9	12/34	35	20
9	Cardiff	Cardiff	149,000	18	16	66	11/98	11	21/84	25	18
10	Preston	Poulton le Fylde, 1	3,144	22	25	53	15/61	25	4/68	6	15
11	Leeds	York	48,737	61	17	22	21/162	13	21/150	14	13
12	Northallerton	Darlington	65,534	23	19	58	12/75	16	0/42	0	10
13	Salisbury	Salisbury	87,000	33	19	47	13/115	11	9/120	8	9
14	Guildford	Guildford	59,500	34	16	50	7/110	6	15/158	9	8
15	Carlisle	Carlisle	52,500	11	12	76	1/160	2	6/33	18	8
16	Bedford	Bedford, 3	8,400	36	17	47	1/57	2	3/39	8	4
17	Preston	Poulton le Fylde, 2	7,148	29	5	65	6/65	9	0/70	0	4
18	Preston	Lytham St Annes	14,699	15	10	75	3/78	4	4/92	4	4
19	Ipswich	Beccles, 3	342	67	33	0	3/79	4	2/88	2	3
20	Worcester	Worcester	11,233	52	35	12	2/59	3	0/17	0	3
21	Southend	Hadleigh	21,537	35	19	46	2/35	6	0/33	0	3
22	Conway	Llandudno	18,492	10	8	82	2/38	5	0/33	0	3
23	Plymouth	Modbury, Street	11,180	9	11	80	1/239	< 1	0/208	0	< 1
24	Bradford	Keighley	46,418	21	19	60	0/25	0	0/52	0	0
25	Hull	Bacon factory	125,000	100	—	—	37/38	97	35/41	85	91
26	Ipswich	Bacon factory	125,000	100	—	—	21/44	48	28/42	67	57
27	Bedford	Bedford, 2	650	29	—	71	0/34	0	—	—	—
28	Leeds	Leeds, 1	236,549	11	24	64	—	—	63/150	42	—
29	Leeds	Leeds, 2	31,662	58	7	34	—	—	28/83	34	—
30	Dorchester	Dorchester	56,000	20	42	38	—	—	26/117	22	—
31	Southend	Rayleigh	5,164	58	15	27	—	—	1/26	4	—
32	Bradford	Bradford	172,680	23	18	59	—	—	0/34	0	—
						Totals	445/2,095	(21·2 %)	485/2,401	(20·2 %)	
							930/4,496 (20·7 %)				

divided into three groups of eight according to the percentage of sheep killed. Table 3 reveals an inverse relation between the percentage of sheep killed at abattoirs and isolations of salmonellae from drain swabs. This observation is in keeping with the known infrequency of salmonellae in sheep in the British Isles. The relation goes some way towards explaining the differences in isolation rates of salmonellae between pairs of abattoirs which slaughtered approximately the same numbers of animals, for example 1 and 18, 6 and 21, and 4 and 14 in Table 1.

Table 2. *Salmonella isolations from abattoir drain swabs and the number of animals killed:* 1961 *and* 1962

No. of abattoirs	Animals slaughtered (thousands)	Drain swabs Examined	Positive	Positive (%)
8	0–12	1377	78	5·7
8	13–36	842	339	40·3
8	46–149	1668	274	16·4

Table 3. *Drain swab isolations of salmonellae from abattoirs killing approximately the same percentage of sheep, or pigs, or cattle*

No. of abattoirs	Animals slaughtered	% of all animals	Drain swabs Examined	Positive	Positive (%)
8	Sheep	0–33	1421	430	30·3
8		41–58	1155	161	13·9
8		60–82	1311	100	7·6
8	Pigs	0–18	1410	268	19·0
8		21–35	1110	99	8·9
8		36–61	1367	324	23·7
8	Cattle	5–16	1502	122	8·1
8		17–20	1143	132	11·5
8		25–61	1242	437	35·2

Similar subdivisions of the twenty-four abattoirs were made in order to analyse the effect of the proportions of pigs and cattle on the isolation rate (Table 3). Little can be said about the effect of the number of pigs, but the increased frequency of the isolation of salmonellae in abattoirs dealing with a high proportion of cattle might explain the differences between the results obtained at Ipswich and Preston (see Table 4), where each laboratory examined by the same technique swabs from two abattoirs in the same area. Results from all abattoirs did not, however, conform to this pattern as may be seen if the following pairs of abattoirs killing approximately the same number of cattle are compared: 6 and 20, 2 and 24, and 5 and 23 (Table 1).

Isolations of salmonellae from abattoirs were thus related to some extent to the predominant animal species killed. In general, a high rate of isolation of salmonellae from abattoirs was associated with a high proportion of cattle; a low rate with a low proportion. The lowest rates of isolation of salmonellae occurred in abattoirs in which a low proportion of cattle and a high proportion of sheep were killed. Among abattoirs where a large proportion of cattle was killed, the highest rate of isolation of salmonellae occurred at Beccles, 1 abattoir (73 % of swabs positive), where most of the cattle killed were aged dairy cows.

Table 4. *The results of laboratories which examined by an identical technique drain swabs from two abattoirs*

		Animals slaughtered				Drain swabs		
			Percentages of					
Laboratory	Abattoir	Total	Pigs	Cattle	Sheep	Examined	Positive	Positive (%)
Ipswich	Beccles, 1	13,347	6	61	33	150	110	73
	Ipswich	21,500	59	30	11	49	15	31
Preston	Poulton le Fylde, 1	3,144	22	25	53	129	19	15
	Poulton le Fylde, 2	7,148	29	5	65	135	6	4

Table 5 presents the frequency distribution of the serotypes and strains of salmonellae isolated from all the abattoir drain swabs examined.

In swabs from abattoirs slaughtering cattle, pigs and sheep, *S. typhimurium* was the dominant serotype, 228 (26 %) of 883 strains, followed by *S. dublin*, 139 (16 %), and *S. heidelberg*, 105 (12 %). Six other serotypes, *S. menston*, *S. senftenberg*, *S. livingstone*, *S. anatum*, *S. meleagridis* and *S. give* accounted for a further 150 (17 %) of the 883 strains. Eighteen strains of *S. paratyphi B* were isolated.

In swabs from the abattoirs which dealt only in pigs, *S. typhimurium* was again the dominant serotype, accounting for 47 (23 %) of 208 strains isolated. Six serotypes, *S. bredeney*, *S. livingstone*, *S. thompson*, *S. menston*, *S. meleagridis* and *S. anatum* were responsible for 82 further isolations (39 %). Four strains (2 %) of *S. heidelberg* and a single strain of *S. paratyphi B* (0·5 %) were also isolated.

In swabs from the Beccles, 1 abattoir, which chiefly slaughtered old dairy cattle, *S. typhimurium* was the dominant serotype, accounting for 30 (26 %) of the 110 strains isolated. Four other serotypes, *S. livingstone*, *S. menston*, *S. kiambu* and *S. schwarzengrund* made up 35 (32 %) of the 110 strains isolated. *S. dublin* was not isolated.

(*b*) *Tissue specimens*

A number of laboratories examined abattoir tissue specimens, usually spleen, liver and mesenteric lymph nodes. Only a few, however, examined specimens consistently throughout 1961 and 1962 and, therefore, the results shown in Table 6 are not as widely representative as are the results from abattoir drain swabs. The pig was the main animal species examined. From 9351 specimens there were 180 isolations of salmonellae (1·9 %). The serotype most frequently isolated was *S. menston*, 41 (23 %), followed by *S. typhimurium*, 36 (20 %), *S. heidelberg*, 22 (12 %), and *S. livingstone*, 11 (6 %).

Table 5. *Salmonella isolations from abattoir drain swabs in* 1961–62

	Abattoirs dealing with cattle, pigs and sheep (numbers 2 to 24). Drain swabs			Abattoirs killing pigs only (numbers 25 and 26). Drain swabs			An abattoir chiefly killing aged dairy cattle (number 1). Drain swabs		
	Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pos. (%)
	4181	699	16·7	165	121	73·3	150	110	73·3

Serotypes and number of strains		Serotypes and no. of strains	Serotypes and no. of strains
adelaide	*meleagridis*, 20	*agama*	*anatum*, 4
agama, 12	*menston*, 39	*anatum*, 10	*bovis-morbificans*
anatum, 22	*mikawasima*, 2	*bonariensis*	*corvallis*
bere	*millesi*	*brancaster*, 9	*cubana*, 3
blockley	*montevideo*, 8	*brandenburg*, 2	*derby*, 4
bovis-morbificans, 5	*muenchen*, 6	*bredeney*, 17	*give*, 3
brancaster, 6	*muenster*	*cubana*, 2	*heidelberg*, 4
brandenburg, 18	*newington*, 5	*dublin*, 5	*kiambu*, 8
bredeney, 17	*newport*, 15	*enteritidis*, 5	*kinshasa*
canastel	*oranienberg*, 4	*frintrop*	*livingstone*, 11
chailey, 3	*orion*	*give*, 6	*manchester*, 4
coleypark	*panama*, 2	*heidelberg*, 4	*meleagridis*
cubana, 2	*paratyphi B*, 18	*kentucky*, 2	*menston*, 9
derby, 14	*poona*	*kiambu*, 4	*montevideo*, 4
dublin, 139	*reading*	*liverpool*, 2	*newington*, 5
enteritidis, 12	*san-diego*, 2	*livingstone*, 16	*paratyphi B*, 3
fayed	*saint-paul*, 13	*manhattan*	*reading*
fresno, 2	*schwarzengrund*, 2	*meleagridis*, 11	*schwarzengrund*, 7
frintrop, 4	*seegefeld*	*menston*, 12	*tennessee*
gallinarum	*senftenberg*, 26	*mgulani*	*typhimurium*, 30
give, 19	*stanley*, 5	*newington*, 2	*uganda*
godesberg	*taksony*, 6	*newport*	*virchow*, 3
havana, 2	*teddington*	*norton*, 2*	unidentified
heidelberg, 105	*tennessee*, 2	*oranienberg*	
infantis, 5	*thompson*, 12	*paratyphi B*	
kentucky, 4	*typhimurium*, 228	*roodepoort*	
kiambu, 6	*uppsala*	*saint-paul*, 4	
lexington	*vejle*, 9	*senftenberg*, 7	
liverpool, 6	*westerstede*, 2	*stanley*, 2	
livingstone, 24	*worthington*, 3	*thompson*, 16	
luke	unidentified, 3	*typhimurium*, 47	
mbandaka, 6		*umbilo*	
		vejle, 4	
		worthington, 2	
		unidentified, 5	

* New serotype: 6,7:i–lw.

Some laboratories examined both bovine and porcine tissues, including liver, spleen, mesenteric lymph nodes, kidneys, muscle tissue, etc. These miscellaneous specimens were not classified under the animal species of origin and form a separate group in Table 6. From 1996 specimens there were 38 isolations of salmonellae

(1·9%). The serotype most frequently isolated was *S. heidelberg*, 21 (55%), followed by *S. dublin*, 6 (16%) and *S. senftenberg*, 4 (11%).

It is evident from these results that offals, and indeed carcass meat, contaminated with salmonellae must have been conveyed to butchers' shops and meat-processing establishments during the period of the investigation.

Table 6. *Salmonella isolations in* 1961–62 *from animal tissues, specimens from butchers' shops and meat products*

Abattoirs: Pig tissues (liver, spleen and mesenteric lymph nodes)			Abattoirs: Tissues other than those exclusively from pigs			Meat factory Drain swabs			Retail butchers' shops: Drain swabs			Retail butchers' shops: Meat and meat products		
Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pos. (%)	Examd.	Pos.	Pc (%
9351	180	1·9	1996	38	1·9	96	11	11	1117	73†	6·5	4127	33	0·

Serotypes	Serotypes	Serotypes	Serotypes	Serotypes
brancaster, 2	*agama*, 2	*bredeney*, 4	*alachua*	*agama*
bredeney, 5	*bredeney*	*give*, 3	*anatum*, 3	*bredeney*, 2
cubana, 5	*dublin*, 6	*lomita*	*brancaster*	*dublin*
derby	*entebbe*	*menston*	*brandenburg*, 3	*gatuni*, 3
dublin, 7	*heidelberg*, 21*	*typhimurium*, 2	*derby*, 7	*heidelberg*, 2
enteritidis, 6	*meleagridis*		*give*, 2	*mbandaka*
frintrop, 4	*muenchen*		*heidelberg*, 3	*meleagridis*, 2
give, 10	*senftenberg*, 4		*infantis*, 4	*newport*, 7
heidelberg, 22	*typhimurium*		*livingstone*, 2	*saint-paul*
kentucky, 3			*manchester*	*senftenberg*, 3
kiambu, 2			*meleagridis*	*typhimurium*,
livingstone, 11			*menston*	
menston, 41			*newport*	
*newport**, 7			*paratyphi B*	
*paratyphi B**, 5			*senftenberg*, 2	
saint-paul, 2			*stanley*	
stanley			*tennessee*, 5	
typhimurium, 36			*thompson*, 4	
unidentified, 10			*typhimurium*, 32	

* Related to human infections.

† Two serotypes were isolated from two of these swabs.

The abattoirs studied varied widely in respects other than the numbers and types of animals slaughtered. Some were old and obsolete, others new, well designed and well equipped: differences also existed in the length of time animals were held in lairages before slaughter, and in the conduct and hygiene of slaughtering. Of these differences, the most important is probably the length of the holding time in lairages (McDonagh & Smith, 1958). Holding times varied from less than 6 hr. to 7 days in the present study; variations were too great to allow any conclusions to be drawn on the relation of this factor to salmonella isolation.

Drain swabs from butchers' shops

The results are summarized in Table 6.

From the drains of retail butchers' shops the serotype most frequently isolated was *S. typhimurium*, 32 (43 %) of 75 strains, followed by *S. derby*, 7 strains (9 %), *S. tennessee*, 5 strains (7 %), *S. infantis* and *S. thompson*, each 4 strains (5 %) and *S. anatum*, *S. brandenburg* and *S. heidelberg*, each 3 strains (4 %).

The results of drain swabs from a meat products factory are also shown in Table 6.

Meat samples from retail shops and food factories

The examination of 4127 specimens of a variety of meat and meat products including raw pork, uncooked meat products such as pie meat, and also potted meat and pies, yielded 33 salmonella isolations (0·8 %). Of these samples, 331 were cooked products which all gave negative results. The serotype most frequently isolated was *S. typhimurium*, 10 strains (30 %), followed by *S. newport*, 7 (21 %), *S. gatuni* and *S. senftenberg*, each 3 (9 %), and *S. bredeney*, *S. heidelberg* and *S. meleagridis*, each 2 (6 %).

The relation between serotypes isolated from abattoirs and from human infections

Table 7 lists the serotypes and strains of salmonellae isolated from abattoirs and from human infections in the areas of the abattoirs. Thirty-eight serotypes were isolated only from abattoirs; thirty-five from both abattoirs and human infections; and twenty from human infections only.

Table 8 compares the serotypes most frequently isolated from abattoirs with those most often isolated from human infections in the areas of the abattoirs. The abattoirs examined were not evenly distributed over England and Wales. No abattoirs were examined in the London area or in the Midlands (Fig. 1).

Three groups of serotypes can be distinguished: one of serotypes isolated frequently from abattoirs but infrequently from human infections (*S. dublin*, *S. livingstone*, *S. senftenberg*, *S. give*, *S. brandenburg* and *S. kiambu*); a second isolated about as often from abattoirs as from human infections (*S. meleagridis*, *S. bredeney*, *S. heidelberg*, *S. menston* and *S. thompson*); and a third group isolated less frequently from abattoirs than from man (*S. typhimurium*, *S. newport* and *S. enteritidis*).

S. typhimurium was the serotype most commonly isolated from both sources. *S. dublin*, a specific bovine pathogen and the second commonest serotype isolated from abattoirs, was rarely isolated from human infections. *S. heidelberg*, the third commonest serotype isolated from abattoirs, was the fourth commonest from human infections.

S. paratyphi B (including *S. paratyphi B* var. *java* and *S. java*) is considered separately from the other serotypes. Between September 1961 and March 1962 *S. paratyphi B* phage-type Beccles var. 5 was isolated on seven occasions from abattoir drain swabs. Five isolations were made from a York abattoir between

Table 7. *Salmonella serotypes isolated from abattoirs (drain swabs and tissue specimens) and from human infections in the area of the abattoirs*, 1961–62

Abattoir but not human	Abattoir and human*	Human but not abattoir
adelaide	*anatum*, 36, 9	*abony*, 3
agama, 15	*bovis-morbificans*, 6, 1	*bareilly*, 5
bere	*blockley*, 1, 3	*bleadon*
bonariensis	*brandenburg*, 20, 8	*cambridge*
brancaster, 17	*bredeney*, 40, 31	*chester*, 2
canastel	*cubana*, 12, 2	*cholerae-suis*, 2
chailey, 3	*derby*, 19, 4	*coeln*, 3
coleypark	*dublin*, 157, 9	*drypool*
corvallis	*enteritidis*, 23, 29	*essex*, 3
entebbe	*give*, 38, 6	*haifa*
fayed	*havana*, 2, 1	*hvittingfoss*, 4
fresno, 2	*heidelberg*, 156, 65	*litchfield*
frintrop, 9	*infantis*, 5, 9	*london*
gallinarum	*kentucky*, 9, 1	*paratyphi A*
godesberg	*livingstone*, 62, 2	*richmond*
kiambu, 20	*manhattan*, 1, 1	*rublislaw*
kinshasa	*meleagridis*, 33, 31	*saarbruecken*
lexington	*menston*, 101, 25	*teshie*
liverpool, 8	*montevideo*, 12, 11	*typhi*, 19
lomita	*muenchen*, 7, 1	*weltevreden*, 3
luke	*newington*, 12, 3	
manchester, 4	*newport*, 23, 122	
mbandaka, 6	*oranienberg*, 5, 2	
mgulani	*panama*, 2, 4	
mikawasima, 2	*paratyphi B*, 27, 49	
millesi	*reading*, 2, 3	
muenster	*saint-paul*, 19, 20	
norton, 2	*senftenberg*, 37, 2	
orion	*stanley*, 8, 17	
poona	*tennessee*, 3, 1	
roodepoort	*thompson*, 28, 67	
san-diego, 2	*typhimurium*, 342, 737	
schwarzengrund, 9	*uppsala*, 1, 1	
seegefeld	*vejle*, 13, 3	
taksony, 6	*virchow*, 3, 2	
teddington		
uganda		
westerstede, 2		
worthington, 5		
unidentified, 19		

* First figure indicates number of strains isolated from abattoirs and tissue specimens; second figure from human incidents.

November and March. Investigations revealed that pigs from a farm attached to a mental hospital were the source of the organism and that an outbreak of infection due to this phage-type had occurred at the hospital concerned between October and December 1961 (Ludlam & Payne, personal communication). A few human infections due to this strain also occurred in various parts of Yorkshire between September and December 1961 but no connexion with meat from York abattoir could be established in these instances. Two other isolations of *S. paratyphi B* phage-type Beccles var. 5 were made from the drain of an abattoir in Beccles, Suffolk, in September 1961. No human infections were recorded in East Anglia at this time and the animal species responsible for the organism could not be traced. Most of the animals killed during this month at the abattoir concerned were cattle or sheep, but also eighty-two pigs were killed during September. *S. paratyphi B* phage-type Battersea was isolated from the drains from the pig slaughter area at Cardiff abattoir in January and July 1962. No cases due to this type occurred in the immediate locality during the relevant times but a human infection was reported in south-west England during the summer of 1962.

Table 8. *Number of isolations of the serotypes found most commonly in abattoirs and in human infections in the areas of the abattoirs*

(The ten most common serotypes from each source are in bold type.)

	Abattoirs		Human infections in area of abattoirs
Serotypes	Drain swabs	Tissues	
S. typhimurium	**300** (23·9%)	**37** (17·0%)	**737** (59·6%)
S. dublin	**138** (11·0%)	**13** (6·0%)	9 (0·7%)
S. heidelberg	**113** (9·0%)	**43** (19·7%)	**65** (5·3%)
S. menston	**59** (4·7%)	**41** (18·8%)	**25** (2·0%)
S. livingstone	**51** (4·1%)	**11** (5·0%)	2 (0·2%)
S. anatum	**34** (2·7%)	—	9 (0·7%)
S. senftenberg	**33** (2·6%)	**4** (1·8%)	2 (0·2%)
S. meleagridis	**32** (2·5%)	1 (0·5%)	**31** (2·5%)
S. bredeney	**31** (2·5%)	**6** (2·8%)	**31** (2·5%)
S. give	**31** (2·5%)	**10** (4·6%)	6 (0·5%)
S. thompson	28 (2·2%)	—	**67** (5·4%)
S. brandenburg	20 (1·6%)	—	8 (0·6%)
S. kiambu	18 (1·4%)	2 (0·9%)	—
S. saint-paul	17 (1·4%)	2 (0·9%)	**20** (1·6%)
S. stanley	17 (1·4%)	1 (0·5%)	**17** (1·4%)
S. newport	16 (1·3%)	**7** (3·2%)	**122** (9·9%)
S. enteritidis	16 (1·3%)	**6** (2·8%)	**29** (2·3%)
S. manhattan	1 (0·1%)	—	1 (0·1%)

All the strains of *S. paratyphi B* belonging to phage-types Beccles var. 5 and Battersea isolated during the survey were slime-wall negative and *d*-tartrate positive; they were, therefore, *S. paratyphi B* var. *java* or *S. java*. Human infections due to this organism usually take the form of food-poisoning and not enteric fever.

Table 9 shows the isolations of phage-types of *S. typhimurium* from abattoirs and from human infections in the area of the abattoirs. Seventeen phage-types (24 strains) were isolated from abattoirs alone: 21 phage-types were isolated from abattoirs and from human infections (265 strains from abattoirs, 593 from human infections in the areas of the abattoirs; there were in addition 45 untypable strains, 20 from abattoirs and 25 from human infections). Fourteen phage-types (55 strains) were isolated from human infections in the area of the abattoirs, but not from abattoirs. Of 648 strains of *S. typhimurium* isolated from human infections in the area of abattoirs and phage-typed, 593 (91·5 %) belonged to 21 phage-types which were also isolated from local abattoirs.

Table 9. *Relationship between phage-types of* Salmonella typhimurium *isolated in* 1961–62 *from abattoirs and from human infections in area of abattoirs*

Abattoir only			Abattoir and human				Human alone		
Phage-type			Phage-type				Phage-type		
Old designation	Prov. new designation	No. of strains	Old designation	Prov. new designation	No. of strains Abatt.	Human	Old designation	Prov. new designation	No. of strains
1 var. 4	U 100	1	1	1	44	41	1b	4a	1
2	10	1	1 var. 2	U 41	5	3	1b	U 59	1
2	U 80	5	1 var. 5	U 9	6	95	2	U 72	10
2b	Untypable	1	1a	2	53	120	2b	14a	3
2c	15a	2	1a var. 1	3 (an.)	14	25	2b	18	5
2d	20a	2	1a var. 2	3 (aer.)	2	29		5a	1
4	U 38	2	1a var. 3	U 57	2	4		22	4
5	26	1	2	9	2	9		80	1
	U 11	1	2	12	7	3		U 25	1
	U 17	1	2	12a	62	79		U 59	1
	U 24	1	2a	13	24	11		U 70	1
	U 77	1	2b	16	4	5		U 80	8
	U 101	1	2b	17	3	74		U 122	1
	U 118	1	2b	20	1	4		U 125	17
	U 119	1	2b	U 107	2	4			
	U 127	1	2c	14	7	55			
	U 131	1	2c	28	2	12			
			4	8	13	15			
				24	4	1			
				32	2	2			
				U 40	6	2			

Note: Forty-five strains were untypable: twenty from abattoirs and twenty-five from human infection

Table 10 compares the phage-types most frequently isolated from abattoirs with those most frequently isolated from human infections in the areas of the same abattoirs. The pattern noted above in connexion with the distribution of serotypes in abattoirs and human infections in the areas of abattoirs again emerges. Certain phage-types were common either in abattoirs or in human infections but not in both; a larger number of phage-types were common to both abattoirs and human infections. In this latter group the association between abattoir isolations and human isolations in the regions of the abattoir was reasonably close.

Abattoir isolations and human infections

The results were analysed to study the relation between abattoir isolations and human infections occurring locally within specified periods of time.

Table 11 presents the figures for abattoir isolations and isolations from human infections in the same area within the same 4-week period, and within the 4-week period immediately preceding or following, for serotypes other than *S. typhimurium* and *S. paratyphi B* during 1961. In seventy-nine (30%) of 263 incidents of salmonella infection listed in Table 11, at least one abattoir isolation was made of

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Table 10. *Frequency of isolation of phage-types of* Salmonella typhimurium *from abattoirs and from human infections in the areas of the abattoirs*

(The ten most common phage-types from each source are in bold type.)

Phage-types: Old designation	Phage-types: Provisional new designation	Abattoir isolations	Human isolations*
2	12a	**62** (21·7%)	**79** (12·6%)
1a	2	**53** (18·5%)	**120** (19·2%)
1	1	**44** (15·4%)	**41** (6·6%)
2a	13	**24** (8·4%)	11 (1·8%)
1a var. 1	3 (an.)	**14** (4·9%)	**25** (4·0%)
4	8	**13** (4·5%)	**15** (2·4%)
2	12	**7** (2·4%)	3 (0·5%)
2c	14	**7** (2·4%)	**55** (8·8%)
	U 40	**6** (2·1%)	2 (0·3%)
1 var. 5	U 9	**6** (2·1%)	**95** (15·2%)
1 var. 2	U 41	5 (1·7%)	3 (0·5%)
2b	17	3 (1·0%)	**74** (11·8%)
1a var. 2	3 (aer.)	2 (0·7%)	**29** (4·6%)
2c	28	2 (0·7%)	**12** (1·9%)
2b	29	2 (0·7%)	11 (1·8%)
6 other types		16 (5·6%)	25 (4·0%)
	Total	266	600

* 112 strains of *S. typhimurium* from human sources were not phage-typed.

Note: Twenty strains isolated from abattoirs and twenty-five strains from human infections were untypable.

the same serotype causing the human infection in the area of the abattoir within 4 weeks, and 53% of the human infections could be related to local abattoir isolations within a period of 12 weeks. Delay in identification of organisms and recording of results must have often considerably increased the time interval between reporting of a human case and the corresponding abattoir isolation.

Table 12 lists thirty-one incidents of human infections due to serotypes which were also isolated from local abattoirs at the relevant time. The incidents are classified according to the likelihood of their being caused by contaminated meat and meat products. In eight incidents, involving a total of 281 infected persons, it was probable that infection was conveyed by meat or meat products. In twenty-three further incidents there may have been a connexion with the isolation of the serotype concerned from the local abattoir or meat product.

DISCUSSION

In sporadic cases of human salmonella infection, the sources and vehicles of infection can rarely be traced. Parker (1954) found that many apparently sporadic infections with *S. paratyphi B* in an urban population could be associated with a few 'prevalences', each of which consisted of a group of cases occurring simultaneously though no common food could be identified. A 'prevalence' is the

Table 11. *Associations in* 1961 *between abattoir isolations and human infections occurring in the same area*

(*S. typhimurium* and *S. paratyphi B* are excluded from this table.)

Serotype	No. of incidents of human infection	No. of times there was association between a human infection and an abattoir isolation: In the same 4-week period	In the preceding or following 4-week period	Total
S. agama	3	2	1	3
S. anatum	16	3	3	6
S. brandenburg	20	11	2	13
S. bredeney	6	2	1	3
S. derby	6	2	1	3
S. dublin	17	9	2	11
S. enteritidis	24	5	6	11
S. give	8	4	2	6
S. heidelberg	26	10	8	18
S. kiambu	2	1	0	1
S. livingstone	3	1	0	1
S. manhattan	8	0	1	1
S. meleagridis	26	7	8	15
S. menston	22	5	3	8
S. montevideo	9	2	3	5
S. muenchen	1	1	0	1
S. newport	19	2	2	4
S. saint-paul	17	4	7	11
S. san-diego	1	1	0	1
S. senftenberg	4	3	1	4
S. stanley	2	0	1	1
S. tennessee	1	1	0	1
S. thompson	22	3	8	11
Totals	263	79	60	139

An abattoir isolation of the same serotype was made in 53% of twelve-weekly periods in which an incident of human infection occurred. Serotypes with no such correlation are omitted from this table.

occurrence within a period of time of a number of cases of infection with the same salmonella serotype or phage-type. McDonagh & Smith (unpublished observations) investigated sporadic cases of salmonella infection in Bradford where children under 5 years of age made up 52% of sporadic infections between 1954 and 1956. They found that, although direct investigation was fruitless, correlation in time of outbreaks and sporadic cases with isolations of salmonella serotypes and phage-types from a local abattoir yielded good evidence that many outbreaks and sporadic cases had their origin in home-produced meat. Harvey & Phillips (1961) made similar observations in Cardiff. Jones, Bennett & Ellis (1961), however, in Coventry found little similarity between serotypes and phage-types isolated from a city abattoir and from human infections in the city over a 12-month period. As independent local investigations might not necessarily reflect the general relation

Table 12. *Incidents of human salmonella infection in which the same organism was isolated locally from meat, butcher's shop or abattoir specimens*

A. *Incidents of human infection in which there was strong evidence that contaminated meat was involved*

(1) Bradford	Aug. 1960–June 1961	111 cases	*S. typhimurium* type 17 isolated from abattoir drain swabs and tissue specimens, the drain of a retail market, pie meat and raw pork
(2) Hull	Apr. 1961	16 cases	*S. meleagridis* in potted meat used in three old people's homes where cases occurred
(3) Hull	Apr. 1961–Sept. 1961	31 cases	*S. typhimurium* type 1 var. 5 in potted meat and in pig tissues from an abattoir
(4) Northallerton	May 1961–June 1961	9 cases	*S. heidelberg* isolated from twenty-three of forty-six abattoir specimens, two drains of butchers' shops and from sausage meat
(5) Dorchester	Oct. 1961	6 cases	*S. saint-paul* in sausage meat in kitchen of hospital where cases occurred and in drain of food factory where the meat was processed
(6) Ipswich	Nov. 1961	4 cases	*S. typhimurium* type 1a var. 1 isolated on five occasions from drain of butcher's shop from which the families purchased pork and sausages
(7) Northallerton	June 1962–July 1962	65 cases (+35 excreters)	*S. newport* isolated from pork sausage meat and pie meat from a retail shop and associated factory. Seven of thirty-seven abattoir drain swabs from abattoir and factory were positive
(8) Winchester	July 1962	4 cases	*S. typhimurium* type 12a isolated from drain of shop from which two patients purchased cooked meat. Abattoir drain also infected

B. *Incidents of human infection in which isolations of the same type were made from abattoirs or meat in the locality but in which no direct connexion could be established*

(1) Winchester	Feb. 1961	1 case	*S. brandenburg*—abattoir drain isolation
(2) Plymouth	Feb. 1961	1 case	*S. dublin* (anaerogenic)—abattoir drain isolation
(3) Hull	Mar. 1961	1 case	*S. saint-paul*—isolated from drain of local bacon factory
(4) Winchester	May 1961–June 1961	2 cases	*S. agama*—abattoir drain positive on five occasions
(5) Northallerton	June 1961–Sept. 1961	37 cases	*S. manhattan*—isolated from drain of bacon factory
(6) Hull	July 1961	1 case	*S. meleagridis*—isolated from drain of bacon factory
(7) Ipswich	July 1961–Sept. 1961	4 cases	*S. typhimurium* type 1a var. 1—butcher's shop and abattoir drains positive
(8) Winchester	Aug. 1961	3 cases	*S. heidelberg*—abattoir drain isolation
(9) Bradford	July 1961–Oct. 1961	13 cases	*S. typhimurium* type 12a—isolated from pig tissues at abattoir
(10) Bradford	Sept. 1961	1 case	*S. give*—isolated from pig tissues at abattoir
(11) Hull	May 1961	4 cases	*S. brandenburg*—isolated from bacon factory
(12) Guildford	Sept. 1961–Nov. 1961	8 cases	*S. typhimurium* type 2c—isolated from pork and from abattoir drains
(13) Bradford	Oct. 1961–Nov. 1961	2 cases	*S. typhimurium* type 1 var. 2—isolated from raw meat and pig tissues at abattoirs
(14) Cardiff	Oct. 1961–Dec. 1961	6 cases	*S. heidelberg* (serological variant)—abattoir drain isolations on five occasions
(15) Ipswich	Nov. 1961	1 case	*S. give*—isolated from pig tissues at bacon factory
(16) Leeds	Nov. 1961–Dec. 1961	5 cases	*S. menston*—two incidents; abattoirs positive on thirteen occasions
(17) Winchester	July 1961–Sept. 1961	4 cases	*S. montevideo*—abattoir drain isolations on two occasions
(18) Hull	May 1962–June 1962	3 cases	*S. saint-paul*—isolated from bacon factory drain
(19) Bedford	May 1962–July 1962	1 case (+2 excreters)	*S. typhimurium* type 1a isolated on three occasions from abattoir supplying butcher's shop used by infected family
(20) Dorchester	July 1962	3 cases	*S. heidelberg*—isolated repeatedly from drain of abattoir supplying butcher's shop used by family concerned
(21) Bournemouth	July 1962	3 cases	*S. typhimurium* type 12a found on twelve occasions in local abbatoir drain during July
(22) Ipswich	Aug. 1962	2 cases	*S. infantis* isolated on four occasions from drain of an abattoir in the area
(23) Bournemouth	Aug. 1962–Oct. 1962	7 cases	*S. typhimurium*, untypable by phage, found in five abattoir drain swabs

Note: The names of the towns are those in which the investigating laboratories are situated.

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between home-killed meat and human salmonella infection, it was hoped that a number of laboratories working in different parts of England and Wales might provide a more general picture.

Salmonellae were isolated from twenty-nine of the thirty-two abattoirs examined. The percentage of positive drain swabs varied widely between abattoirs. This was evident not only between abattoirs in the same area examined by one laboratory, but also in the same abattoir examined by the same laboratory in different years. Variations in the isolation of salmonellae from different abattoirs were not likely, therefore, to be due to individual differences in either the frequency of examination of swabs or the laboratory techniques of collection and examination of swabs.

The differences in salmonella isolations from abattoirs did, however, appear to be related to the species of animals killed. In general, salmonellae were isolated more often from abattoirs killing a large proportion of cattle and less often from abattoirs where few cattle were killed in proportion to sheep. The importance of cattle as a source of *S. typhimurium* infection was first pointed out by Anderson (1960); he analysed the distribution of phage-types in animals and man and concluded that cattle and fowls were the main animal sources of human infection during the period of his survey. The influence of the proportion of pigs killed on salmonella isolations from abattoirs proved more difficult to assess. High isolations of salmonellae were recorded at the two bacon factories examined (91 and 57 % of swabs positive), but the number of pigs killed each week at these factories was greater than the number killed annually at many of the other abattoirs. One laboratory (Ipswich), however, examined swabs from an abattoir (no. 1) killing annually approximately 8000 aged dairy cows and from a bacon factory (no. 26) killing annually 125,000 pigs. Salmonella isolations from drain swabs were 73 and 57 %, respectively (Table 1). On balance it appears that the proportion of pigs killed influenced the salmonella isolations from abattoirs much less than the proportion of cattle.

In connexion with pigs, it is noteworthy that no isolations of *S. cholerae-suis* were made during the survey. The significance of this observation is difficult to assess, because selenite F broth was used as an enrichment medium for many of the specimens; Smith (1952) reported that selenite broth was not a suitable culture medium for *S. cholerae-suis*. Another possibility is that intestinal carriers of *S. cholerae-suis* may be rare among healthy pigs which are sent for slaughter.

Culture of drain swabs from abattoirs provides ample evidence of the presence of salmonellae in the intestines of animals, but the presence of salmonellae in animal tissues is a more reliable index of carcass contamination and provides a link between abattoirs and butchers' shops. If tissue samples are regarded as representative of carcass meat, which some may question, approximately 2 % of carcasses at abattoirs immediately after killing were probably contaminated with salmonellae.

A direct link is thus established between the abattoir and the butcher's shop. Eighteen of thirty-five serotypes isolated from abattoir drain swabs and from human infections (Table 7) were isolated from animal tissues at the abattoir.

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Fourteen of these eighteen serotypes were isolated also from butchers' shop drains or from meat products. *S. heidelberg*, *S. meleagridis*, *S. newport*, *S. senftenberg* and *S. typhimurium* were isolated from abattoirs, animal tissues at the abattoirs, butchers' shop drains, and meat or meat products.

Seven of thirty-eight serotypes isolated from abattoir drain swabs but not from human infections were isolated from animal tissues. Four of these seven serotypes were also isolated from butchers' shop drains or from meat and meat products. Of the serotypes isolated from abattoir drain swabs, those which were also found in animal tissues were more common than those which were not. There may therefore be a quantitative variation in the contamination of carcass meat with salmonellae, and this suggestion is supported by the analyses of human infections discussed in the next paragraph. Two serotypes, *S. alachua* and *S. gatuni*, were isolated from a butcher's shop drain and from butcher's meat, but not from tissues or abattoir drains. It is possible that these strains were derived from sources other than home-killed meat, such as fowls or imported meat.

The relation between contaminated meat and human infections must now be examined. Perfect agreement between contaminated meat from abattoirs and human infections is difficult to show, since meat from an abattoir is often distributed to and consumed in distant areas. For example, carcass trimmings from an East Yorkshire bacon factory were sent for processing and distribution to West Yorkshire, and pie meat was sent to the London area. A relation between abattoir isolations and human infections might be expected more frequently in large outbreaks than in sporadic cases not only because outbreaks are generally investigated more thoroughly, but also because it is likely that contamination is then widespread in abattoirs and food premises and is thus more likely to be detected. Table 12 lists eight outbreaks in which the chain of infection could be traced back through meat or butchers' shops to abattoirs, and twenty-three outbreaks or sporadic cases in which a close relation in time with abattoir isolations was shown. Most human salmonella infections, in England and Wales are however, sporadic cases in which the vehicle of infection is rarely identified. Table 11 shows that many sporadic cases had a close association in time with the isolation of the infecting serotype from an abattoir, and could be classed as 'prevalences' (Parker, 1954); 30 % of sporadic human infections occurred within the same 4-week period as the isolation of the infecting serotype from the abattoir. If the period of time be extended to 12 weeks, to cover the inevitable delays in the identification of serotypes and notification of human infections, 53 % of sporadic human infections could be related to an abattoir isolation.

In addition, many of the serotypes isolated most frequently from abattoirs were also the serotypes most commonly isolated from human infections. Thirty-five serotypes were isolated both from abattoirs (drain swabs and tissue specimens) and from human infections (Table 7). Eighteen of the serotypes were also isolated from animal tissues, and these eighteen serotypes were responsible for 1153 (90 %) of 1282 human infections. The five serotypes isolated from abattoirs, tissues, butchers' drains, and meat products (*S. heidelberg*, *S. meleagridis*, *S. newport*, *S. senftenberg* and *S. typhimurium*) were isolated from 956 (75 %) of 1282 human infections. The seventeen serotypes isolated from abattoirs and human infections but not from tissues were found in only 129 (10 %) of 1282 human infections. *S. thompson*, which is commonly isolated from fowls and egg products, accounted for 67 of these 129 human infections.

These findings would seem to establish evidence of a chain of infection from abattoirs via retail butchers' shops and meat and meat products to man. Healthy animals are known to harbour salmonellae in the intestine (Field, 1948; Smith, 1959, 1960) and after leaving the farm there are many opportunities for cross-infection of animals before reaching the abattoir (Anderson *et al.* 1961). The salmonellae isolated from animal tissues at the abattoir are probably the result of surface contamination from the intestinal contents of apparently healthy animals, but it is possible that invasion of deep tissues may occur post-mortem, or ante-mortem in animals exhausted through physical stress (Jepsen, 1957). The factors leading to severe abattoir contamination may be manifold, however, and probably include the numbers of infected animals entering the abattoir, the length of holding time before slaughter, and the general hygiene of the abattoir. With reference to the numbers of infected animals entering the abattoir, it may be noted that continuous observation of a herd of sixty calves in 1960 showed the occurrence of a sudden brief outbreak of infection with *S. typhimurium* phage-type 1a in which at least 50 % of animals were excreting enormous numbers of salmonellae but showed only mild evidence of constitutional upset (Wormald, personal communication). It seems likely that routine slaughter of such a group of animals during the period of symptomless infection could initiate a widespread outbreak of human infection; contamination of the abattoir might persist for some time after the infected animals were killed, and an outbreak could be prolonged in this way.

As to the role of home-produced meat in salmonella infection in England and Wales, it has already been noted that only on two occasions were serotypes isolated from butchers' shop drains or meat which were not isolated from abattoirs. In this investigation 2 % of animal tissues from abattoirs were found contaminated with salmonellae. This figure is regarded as indicative of carcass contamination and is to be compared with 4·3 % of imported chilled carcasses and 10·3 % of imported frozen boneless meat found contaminated in 1956–59 (Hobbs & Wilson, 1959); during this period home-produced meat formed 65 %, imported chilled and frozen meat 35 %, and boneless meat 0·3 % of meat consumed (Report, 1962*b*). Both home-produced and imported carcass meat are sources of human salmonella infection. The amount of imported boneless meat consumed is small compared with that of carcass meat, but a much higher proportion of samples are found to be contaminated; furthermore, this material is used in manufacturing establishments and for large-scale catering.

As to the prevention of human infection from home-killed meat, the greatest return may be expected by concentrating on the prevention of cross-contamination in the abattoir, which serves as a centre both for the collection of animals for slaughter and for the distribution of meat. Attention should also be directed to markets and dealers' premises as the places where cross-infection of animals is most likely to occur in transit from farm to abattoir.

Attention should finally be directed to infection of individual animals on the farm. Field (1959) has described a system of control measures under which clinical salmonellosis of adult cattle would be a notifiable disease, leading to the identification of infected or excreting animals in herds.

SUMMARY

In 1961 and 1962 a Working Party of the Public Health Laboratory Service, in which twenty-two laboratories participated, investigated the occurrence of salmonellae in abattoirs, meat factories, butchers' shops and meat products, and their association with human infections.

Thirty-two abattoirs were studied. Salmonellae were isolated from 930 (21 %) of 4496 swabs of abattoir drains. There was great variation between different abattoirs, but in general salmonellae were found most frequently in those which slaughtered a high proportion of cattle and a low proportion of sheep; more serotypes were isolated from bacon factories than from abattoirs which slaughtered more than one species of animal. Of 11,347 tissue specimens collected at abattoirs, 218 (1·92 %) yielded salmonellae.

Drain swabs from butchers' shops were examined and 73 (6·5 %) of 1117 swabs were positive. Meat and meat products were less commonly contaminated but 0·8 % of 4127 samples yielded salmonellae.

Salmonella typhimurium was the serotype isolated most frequently from all sources. It was often shown that the same serotypes or phage-types were occurring in abattoirs and in human cases in an area at the same time. In eight food-poisoning incidents, involving a total of 281 cases and excreters, there was convincing evidence that meat or a meat product was the vehicle of infection; in a further twenty-three incidents the organisms causing disease were isolated from sources which suggested that infection might have been meat-borne.

The evidence collected suggests that cattle introduce salmonellae into abattoirs more often than other species of animals. The importance of pigs as a source of human infection is confirmed. Sheep are not a source of salmonella infection in man from meat and meat products, whereas meat from pigs, cattle and calves is a source of infection and is responsible for both sporadic cases and outbreaks of disease.

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