J. Hyg., Camb. (1966), **64**, 411
Printed in Great Britain

An epidemiological study of *Salmonella* in a closed pig herd

By T. W. HEARD
19 *Langley Road, Chippenham, Wilts.*
and A. H. LINTON
Department of Bacteriology, University of Bristol

(*Received* 11 *May* 1966)

Various data concerning salmonella excretion in the faeces of groups of animals and birds have been described: in pigs (Hansen, 1964; Zagaevskii, 1962; Kampelmacher, Guinée, Hofstra & van Keulen, 1963; Gaugusch, 1963); in calves (Wormald, Creasby & Venn, 1965); in mice (Morello, Digenio & Baker, 1965); and in pigeons (Neilsen, 1965). Little work however has been done on analysing the results of repeated examinations over a period of time, particularly where it concerns the epidemiology of the infection inside a closed community of farm animals. The present paper describes an attempt at such an analysis.

An outbreak of clinical salmonellosis in a closed herd of hysterectomy-produced pigs during 1963/64 was described by Heard, Linton, Penny & Wilson (1965). It was decided to use this herd of pigs, in which salmonella infection had become established, for an epidemiological study. Previously only a brief reference was made to the subsequent pattern of salmonella excretion in the herd, and this is extended in this communication.

Regular faecal examinations from all occupied pens on the farm were made and the findings correlated with records of all animal movements and routine activities of the farm staff. By this means it was possible to establish the major factors responsible for the spread of salmonella infection within this closed community.

MATERIALS AND METHODS

The earlier examinations for *Salmonella* were carried out using individual rectal swabs of all the pigs on the farm. This was necessary since at that time some pens had communal dunging passages, which allowed cross-infection to occur, and hence the individual animal was the unit of examination. In order to limit cross-infection after the initial outbreak all pens were converted to individual dung disposal. Since each pen was now segregated, a small trial was carried out to compare the numbers of salmonellas that could be isolated from pen faecal samples, with those isolated from individual pig rectal swabs. The pen faecal samples were collected in polythene bags, the bag being extruded so that it formed a glove around the hand. In pens containing more than one pig, six or seven samples of freshly voided faeces were picked up from different parts of the same pen, care being taken to avoid treading on any area before taking the sample. This method was similar to that described by Kampelmacher *et al.* (1963)

and Guinée, Kampelmacher, Hofstra & van Keulen (1965). Rectal swabs of about 0·5 g. of faeces were incubated overnight in selenite broth and subcultured on deoxycholate citrate agar. Non-lactose fermenting colonies which grew after 24 and 48 hr. incubation were tested for urease production, to eliminate species of *Proteus*, and all urease-negative strains were tested biochemically and serologically to identify specific *Salmonella* serotypes. Strains of *Salmonella typhimurium* were phage-typed. The results are shown in Table 1 and a summary of the findings in Table 2.

Table 1. *A comparison of methods used for detecting* Salmonella

Pen no.	Salmonella isolations by: Pen faecal examination	Salmonella isolations by: Rectal-swab examination	Ratio of salmonella positive rectal swabs to total examined
1	–	–	0/13
2	–	–	0/11
3	–	–	0/9
4	–	–	0/1
5	–	–	0/7
6	–	–	0/10
7	–	–	0/10
9	–	+	3/11
10	+	–	0/1
11	+	+	1/1
12	+	+	1/1
13	+	–	0/1
14	–	–	0/8
15	–	–	0/7
16	–	–	0/1
17	–	+	6/11
18	+	–	0/1
Totals	5/17	4/17	11/104

Table 2. *Summary of data set out in Table* 1

Nature of isolation	No. of pens from which salmonellas were isolated by the different methods: Pen faeces examination	Rectal swab examination	Either method
Both methods	2	2	2
Faeces only	3	0	3
Rectal swab only	0	2	2
Totals	5	4	7
% of all pens infected	29·4	23·5	41·0

https://doi.org/10.1017/S0022172400040717 Published online by Cambridge University Press

TRIAL RESULTS

Of the 104 rectal swabs examined, 11 were positive for *Salmonella* but despite the large number of examinations made only 4 pens were shown to be infected. By pen-faeces examination 5 pens were shown to be infected. The results of both methods did not show perfect correlation. Of the 7 infected pens, only 2 were positive by both methods, 2 by rectal swab examination only and 3 by the pen faecal sampling only. It is evident from this limited survey that neither method is significantly superior to the other, but the use of both methods gives higher incidence than either method alone. On the other hand, on the evidence presented, examination of pen faecal samples, whilst involving far less laboratory work, achieved similar results to those obtained by the examination of a far greater number of rectal swabs. In summary, 17 faecal sample examinations gave similar results to 104 rectal swab examinations. Both methods emphasized the need for repeated examinations before any assumption could be made that a pen was free from salmonella organisms.

Table 3. *Isolations of* Salmonella *from pig-pen faecal samples examined at fortnightly intervals from* 29 *March to* 12 *July* 1965

	Fortnightly period									
No. of pens examined	1 73	2 90	3 91	4 63	5 79	6 84	7 97	8 84	Totals 661	% positive
	Salmonella serotypes isolated									
S. typhimurium										
Type 1	4	1	2	1	1	0	0	0	.	.
Type 29	2	2	2	1	1	2	1	2	.	.
Type 30	0	0	1	1	2	2	0	0	.	.
Untyped	1	1	0	0	1	1	0	0	.	.
Totals	7	4	5	3	5	5	1	2	32	4·8
S. bredeney	11	6	15	6	6	7	9	9	69	10·4
S. durban	0	0	0	0	5	1	7	4	17	2·6
S. heidelberg	0	0	0	0	1	4	3	3	11	1·7
S. orion	2	0	0	0	0	0	0	0	2	0·3
Totals per fortnight	20	10	20	9	17	17	20	18	131	19·8
% salmonella-positive pens	27·4	11·0	22·0	14·3	21·5	20·2	20·6	21·4		

Since the epidemiological survey was to be based on the presence or absence of salmonellas from pens rather than individual animals, and in the light of the results of the comparison of methods reported above, it was decided to use pen-faecal sampling in this study. Each pen was sampled every 2 weeks, half the farm being sampled each week. The results were recorded on a ground plan of the farm, as were all the movements of pigs. Pigs were only moved for three reasons: when being moved to a new pen, during service and when moved for weekly weighing.

The farm consisted of six houses. These housed breeding sows and gilts, boars, farrowing sows and gilts, young boars on performance test, young weaned gilts and older gilts. During the investigations no males or females were retained after

they had produced one litter. The only animals to remain on the farm were vasectomized boars which occupied pens adjacent to the sow pens in the sow yard.

The bacteriological findings, over a 16-week period, are set out in Table 3. During the period five different sero-types were found to be present for part or the whole of the period, and for one of these, *Salmonella typhimurium*, three phage-types were identified. An average of 19·8% infected pens was recorded throughout the period. It must be emphasized that the infected-pen rate does not represent the salmonella pig carrier rate. In our experience the percentage of infected pens is always higher than the carrier rate as determined by individual rectal swab examinations. This is supported by an analysis of figures previously published (Table 4). In the present survey, an average of 19·8% infected pens would therefore most probably represent an individual salmonella carrier rate of the order of 8%.

Table 4. *The percentage of salmonella infection by individual pig examinations compared with the percentage of pens infected*

(Data from Heard *et al.* 1965).

	% salmonella infection	
Sampling date (1964)	Pigs infected (by rectal swabs)	Pens infected
6 July	8·3	25·3
27–30 July	7·2	26·0
14–17 September	24·2	56·0
29–31 December	15·9	37·0

ANALYSIS OF THE RESULTS

In order to correlate the presence of salmonellas in any particular pen with the movement of pigs within the farm, a number of arbitrary standards had to be laid down. It was decided to analyse within the scope of the 16-week period the history of all newly formed pens of pigs. This necessitated knowing the salmonella history of these pigs while in their previous pens. For inclusion in this survey these newly formed pens had to be continuously occupied by the same pigs for a period of not less than 4–6 weeks, that is, the time required to complete three fortnightly bacteriological examinations on pen faecal samples. Seventy eight pens met these requirements.

The decision to require a minimum of three bacteriological examinations was based on a number of observations. In this survey, 129 examinations were made on pens which proved to be infected with *Salmonella* but, of these, salmonellas were isolated from only 63 specimens. This suggests that we were successful in detecting salmonellas by our technique with only half the specimens. At least two examinations are therefore necessary to detect infected pens and the requirement of three examinations, we consider, gave reasonable coverage. Further, three fortnightly examinations were often the largest number which could be fitted in before animals became due for a routine move to another pen. We considered also that since in medical practice three negative specimens are often considered a

reasonable number before giving a human carrier clearance, this number was also reasonable in this present survey.

The findings of the seventy-eight pens and their subsequent pattern of salmonella excretion were followed. The pens were classified according to whether they were formed with pigs having a history of either a complete absence of salmonellas, or coming from pens from which salmonellas had been previously isolated. A further subdivision of the first class was made according to whether or not pens adjacent to the pen from which the pigs were taken had a history of salmonella infection. These three classes are set out in Table 5.

Table 5. *Epidemiological analysis of pen-sample results*

	History of pens from which new pens were formed			
	Pigs from salmonella −ve pens with adjacent pens −ve	Pigs from salmonella −ve pens with adjacent pens +ve	Pigs from salmonella +ve pens	Totals
No. of pens	11	26	41	78
Pens −ve after three examinations	11	18	28	57
Pens +ve during three examinations	0	8	13	21
Pens becoming +ve after three successive −ve results	2	2	4	8

DISCUSSION

The results can be adequately discussed only against the background of the strict hygiene measures taken on the farm. All attendants entering the farm were required to dress in newly laundered clothes and head covering and to put on gum boots used exclusively at the farm. Each house had its own attendant, and access to the house required the use of a disinfectant foot bath. The attendant entered each pen daily to brush it clean. Each pen was supplied with its own brush and care was taken to avoid carrying faeces from pen to pen within a house. Each week pigs from pens in the Early Rearing, Final Rearing and Performance Test Houses were weighed in the communal weigh pen. No precautions were taken between weighing each pen but full disinfection procedures were carried out between weighing pigs from each house. After a pen was emptied, before restocking, the walls and floor were thoroughly cleansed and disinfected and this was followed by a disinfectant/cement wash treatment of the walls. As a result of this procedure we have every confidence that no residual infection remained in the pens. During the period under survey, fifty-nine pens were cleaned and later restocked. Twenty-four of these were infected with *Salmonella* before and only six became subsequently infected after restocking and in each case an external source of infection was known. All houses save the sow and boar yards were

generally completely depopulated between pen occupation. The pens were of the usual commercial type, with concrete floors, cement rendered walls up to 3ft. 6 in. high, and galvanized iron fittings.

Although we have not isolated salmonellas from the pig food, there is considerable indirect evidence that the initial salmonella infection entered the farm in food. In July 1964 two salmonella serotypes were found; subsequently between July and December 1964 three other serotypes appeared (see Table 4). From December 1964 the food has been specially treated ensuring a minimum temperature of 145° F. in preparation followed by processing in small nuts which involves a further temperature treatment, and since this date no further salmonella serotypes have appeared. It would seem that for the last 12 months the outside source of infection has been controlled. Cross-infection on the farm must therefore be the result of activity within the farm. Birds are excluded from the houses and there is no evidence of rodent infestation. The main vehicles of cross-infection must be by direct faecal contact following pig movements, by pen mixing or service, by aerial spread or by the mechanical transfer of infection by the attendants.

In the light of these observations an interpretation of our results is possible.

In the first group of eleven pig pens, formed from non-infected pens with adjacent pens negative, all (100%) remained free from infection for a period of 4–6 weeks. Subsequently two became infected, but the source of these infections is not known.

In the second group, out of 26 pens, formed from previously non-infected pens, but with adjacent pens infected, 18 (69%) remained free from infection whilst 8 became positive. This would suggest that cross-infection between pens does occur possibly as a result of movements of farm attendants between pens, consecutive movement of pens for weighing or air-borne spread.

In the third group, of 41 pens formed from previously infected pens, 28 (68%) subsequently proved to be non-infected within the 4- to 6-week period. From these observations it may be concluded that in a high proportion of pens (in this case 68%) salmonella infection was self-limiting. Of these pens only 4 subsequently became positive during the duration of the trial, (i.e. up to 16 weeks).

From experience gained with this closed herd of pigs we are convinced that the major source of cross-infection is contact between healthy stock and infected faeces. This occurs when pens are mixed together, following pen-to-pen transfer of infection on the boots of farm attendants or following the movement of pens through a communal weighing area. This mode of cross-infection could also explain two infections which occurred following service of sows by infected boars.

By excluding an external source of infection it was possible to predict, with a fair degree of certainty, the position of pen infection simply by recording the movements of animals, and knowing their original bacteriological status.

As a result of the breeding programme on this farm it has not been possible to introduce all the control measures (especially the avoidance of excessive movement of pigs) which we are confident would speed up the reduction in the rate of cross-infection. Having controlled the external source of infection, the conditions necessary for salmonella control would seem to be: (1) the penning of pigs in

small groups with no contact with faeces of other pigs on the farm; (2) observing elementary hygiene measures when moving pigs from one house to another; (3) keeping pen-to-pen movement of both pigs and attendants to a minimum.

It seems reasonable to suggest that the methods of investigation on this farm provide a system for tracing enteric infection which might well be applied on a wider national and international scale, and should be of prime importance in the designing of farming systems.

SUMMARY

An epidemiological survey of salmonella infection in a closed herd of pigs is reported. The main cause of cross-infection resulted from the movement of animals, with subsequent mixing of infected and clean stock and exposure of non-infected animals to infected faeces. Pen-to-pen infection carried by farm attendants also proved important.

An extended survey is at present being conducted to gain further information on the processes of cross-infection.

We wish to acknowledge the practical help and advice given throughout this survey by the staff of the pig unit, by Professor Grunsell, Department of Veterinary Medicine, University of Bristol, and Professor Cooper and the technical staff of the Department of Bacteriology, University of Bristol. We are indebted to Dr E. S. Anderson for phage-typing the strains of *Salmonella typhimurium*.

REFERENCES

Gaugusch, Z. (1963). Occurrences of Salmonella in normal slaughter pigs and pigs experimentally infected with swine fever. *Symp. int. Ass. vet. Fd Hyg.* no. 3 (Nice, 1962), pp. 80–1.

Guinée, P. A. M., Kampelmacher, E. H., Hofstra, K. & van Keulen, A. (1965). *Salmonella* in piglets in the Netherlands. *Tijdschr. Diergeneesk.* **90**, 787.

Hansen, R. (1964). *Salmonella* infection in healthy pigs. *J. Am. vet. med. Ass.* **145**, 139.

Heard, T. W., Linton, A. H., Penny, R. H. C. & Wilson, M. R. (1965). *Salmonella typhimurium* infection in a hysterectomy-produced herd of pigs. *Vet. Rec.* **77**, 1276.

Kampelmacher, E. H., Guinée, P. A. M., Hofstra, K. & van Keulen, A. (1963). Further studies on *Salmonella* in slaughterhouses and in normal slaughter pigs. *Zentbl. VetMed.* **10**, 1.

Morello, J. A., Digenio, T. A. & Baker, E. E. (1965). Significance of *Salmonella* isolated from apparently healthy mice. *J. Bact.* **89**, 1460.

Neilsen, B. B. (1965). Diagnosis and treatment of *Salmonella typhimurium* infection in pigeons. *Nord. VetMed.* **17**, 156.

Wormald, P. J., Greasby, A. S. & Venn, J. A. J. (1965). An epidemic of *Salmonella typhimurium* infection in calves. *Mon. Bull. Minist. Hlth* **24**, 58.

Zagaevskii, I. S. (1962). Epidemiological role of carriers in salmonellosis in pigs and cattle. *Veterinariya*, no. 9, p. 15. Abstract in *Vet. Bull., Weybridge* (1963), **33**, 292.