J. Hyg., Camb. (1984), 93, 539–546
Printed in Great Britain

Further observations on the excretion of salmonella in the faeces of calves fed milk substitute

BY M. HINTON, I. O. SULEYMAN, VIVIEN ALLEN

Department of Veterinary Medicine, University of Bristol, Langford House, Langford, Avon BS18 7DU, U.K.

AND A. H. LINTON

Department of Microbiology, The Medical School, University of Bristol, Bristol BS8 1TD, U.K.

(*Received* 12 *June* 1984; *accepted* 6 *July* 1984)

SUMMARY

Swabs of rectal faeces were obtained daily for 28 days from 90 calves reared in five batches during the summer of 1983. The calves were purchased unweaned in markets and fed a milk-substitute diet. *Salmonella typhimurium* phage type DT204c was isolated from calves in four batches and *Salmonella newport* from one. When the data from the 90 calves were considered together the incidence of salmonellas, excretion rose to peak between 5 and 7 days after purchase before declining to low levels during the fourth week. Salmonella was isolated from 55 (61%) calves; 30 were positive on up to four occasions while 21 and 4 animals respectively were positive between 5 and 11 and 15 and 20 times. In the majority of animals infection was probably subclinical since treatment with antibacterial drugs and excretion of *S. typhimurium* coincided in four calves only.

INTRODUCTION

In an earlier study, faecal excretion of *Salmonella* spp. was monitored in 495 market calves reared in 16 batches (designated 1–16) during 1979 and 1982 (Hinton *et al.* 1983). The rate of isolation of *Salmonella typhimurium* was either zero or relatively low on arrival at the rearing farm. The incidence rose to a peak in the second or third week before declining to low levels by the end of the fourth week. However, as the animals were only sampled 5–9 times during a 4- to 5-week rearing period, it was neither possible to assess the duration of excretion of *S. typhimurium* in individual animals nor to relate excretion precisely to oral treatment with antibacterial drugs.

This paper reports a more detailed survey carried out in 1983. It involved five additional batches of calves in which animals were sampled daily during the 4 weeks after their arrival on the farm.

MATERIALS AND METHODS

The calves and their management

The calves, all Friesians, were purchased in markets during May and June 1983 and transported by road to the rearing farm in the county of Somerset. Four of the five batches, designated 17–20, were housed in the same shed as used to rear the 12 batches monitored in 1982 (shed A). The fifth batch (no. 21) was accommodated in a second shed on the same site (shed B). Shed A comprised eight rooms each with two ranks of 18 individual wooden pens on each side of the room while in shed B there were four rooms each housing 54 calves in six separate ranks of nine wooden pens.

The calves were fed twice daily (once on Sundays) with a milk-substitute diet which contained the growth-promoting antibiotics flavomycin and zinc bacitracin.

A variety of parenteral and oral antibacterial drug preparations, obtained from a veterinary surgeon, were used to treat animals which showed signs of clinical illness. The days on which drugs were administered orally to individual animals was recorded.

The ear tag number of each calf in the four batches (17–20) reared in shed A was noted and the probable region of the farm of origin determined from the MAFF register of farm code numbers.

Sampling protocols

In 1982, 162 calves in batches 7, 8, 9, 15 and 16 had been sampled twice weekly (Hinton *et al.* 1983). In order to obtain a direct comparison with the situation in that year all the 144 calves in batches 17–20 were also sampled twice weekly.

In the more detailed investigation 18 of the calves, all of which occupied adjacent pens on one side of the room, were swabbed daily for 28 days, as were an additional 18 calves, kept in two ranks of nine pens in a room, in shed B (batch 21).

Bacteriological methods

Swabs of rectal faeces were processed within 2 h of collection. The methods for isolation and identification of salmonella were the same as those employed in 1982 (Hinton *et al.* 1983).

Representative *S. typhimurium* isolates were sent to the Salmonella and Shigella Reference Laboratory, Colindale Avenue, London, for phage typing.

RESULTS

None of the calves reared in the five batches died during the survey period. *S. typhimurium* phage type DT204c was isolated from calves in batches 17, 18, 19 and 21 and *S. newport* from animals in batch 20.

Comparison of salmonella excretion in 1982 and 1983

In shed A the isolation rate of salmonella from animals in 1983 was lower than it was in 1982 (Fig. 1). In 1983 fewer calves originated from farms in Wales and more from farms in the S.W. of England than in 1982 (Table 1). In the two years

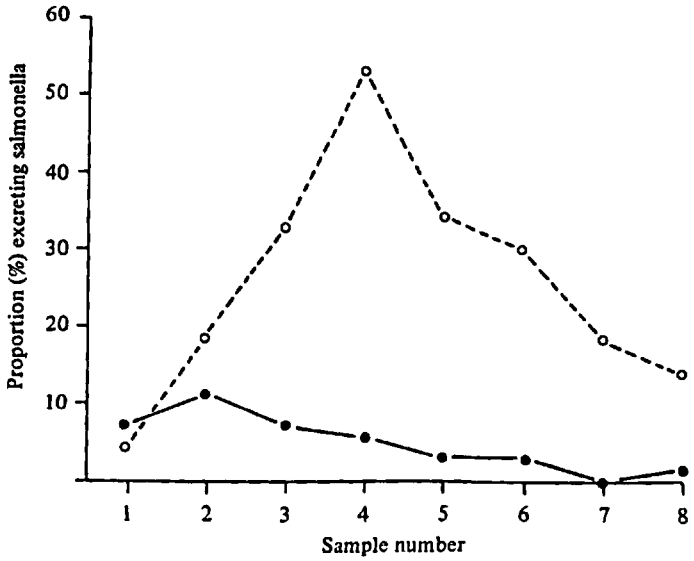

Fig. 1. The incidence of faecal excretion of salmonella by calves reared in shed A in 1982 (○) and 1983 (●) and which were sampled twice weekly.

Table 1. *Distribution of calves reared in shed A during* 1982 *and* 1983 *according to the region of the farm of origin*

	1982*		1983†	
Region	No. of calves	%	No. of calves	%
England				
Northern	32	19·8	20	13·9
Midland	19	11·7	19	13·2
East and South East	10	6·2	7	4·9
South West	12	7·4	41	28·5
Scotland	26	16·0	32	22·2
Wales	46	28·4	21	14·6
Not known	17	10·5	4	2·8
Total calves	162		144	

* Batches 7, 8, 9, 15 and 16. Hinton *et al.* (1983), table 9.
† Batches 17 to 20.

the difference in the distribution of the calves, according to the region of their probable origin, was statistically significant ($\chi^2_{(6)} = 32$; $P < 0{\cdot}001$).

Daily excretion of salmonella

The incidence of infection differed considerably between batches, being lowest in batch 20 and highest in batch 21. The findings in each batch can be summarized as follows:

Batch 17. Twelve of the 18 calves excreted *S. typhimurium* 1–11 times; eight of these animals excreted within the first 15 days and formed three separate clusters of two or three calves, namely, 17/3 to 17/6, 17/8 and 17/9 and 17/12 to 17/14. The other four calves which excreted once only were positive on the last sampling

https://doi.org/10.1017/S0022172400065116 Published online by Cambridge University Press

occasion. In two of three calves which received antibacterial drugs, dosing coincided with salmonella excretion.

Batch 18. The excretion patterns for the calves in this batch are summarized in Table 2. All but one of the 10 excretors were in adjacent pens (18/3–18/11). In several animals excretion was sporadic (e.g. 18/3, 18/6, 18/8 and 18/11) while in others it was continuous over periods of 6 days or more (18/4, 18/9 and 18/10).

Batch 19. Eleven of the 18 calves excreted *S. typhimurium* once or twice between days 2 and 20. Four calves were treated with oral antibacterial agents between days 7 and 13. In no case did excretion and treatment occur concurrently.

Batch 20. Four calves excreted *S. newport* once or twice during the first 7 days. Two calves were treated on days 19 and 20.

Batch 21. The incidence of salmonella infection was higher in this batch than in the other four. All 18 calves excreted *S. typhimurium* at least once although none was positive before the third day when seven calves were positive (Table 3). Antibacterial drug dosing occurred sporadically in several of the calves although only two (21/10 and 21/12) were dosed on two or more consecutive days on which *S. typhimurium* was also isolated.

When the data from all five batches were considered together the incidence of salmonella excretion was shown to rise during the first few days to peak between 5 and 7 days before declining to low levels during the fourth week (Fig. 2). Salmonella was isolated from 55 (61 %) of the 90 calves. The cumulative number of excretors increased rapidly during the first week of residence on the farm. In contrast, only eight new excretors (14 % of all excretors) were identified in the second half of the rearing period (Fig. 2).

The total number of days on which salmonella was isolated from rectal swabs varied up to 20 (Fig. 3). The animals could be subdivided arbitarily into three unequally sized categories, namely animals excreting $\leqslant 4$ times, and those which excreted 5–11 times, and > 11 times respectively.

Correlation between excretion and treatment

The majority (77 %) of the 90 calves swabbed daily received no antibacterial drug treatment. Twelve of the 21 treated animals were treated on 1 day only, three on 2 and 3 days respectively, two on 4 days and one calf on 6 days. Only four calves, in batches 17 and 21, were treated on two or more consecutive days (i.e. at least three times) coincidently with the excretion of salmonella.

DISCUSSION

This investigation represents an extension of studies carried on this farm in 1979 and 1982 (Hinton *et al.* 1983). In the event the situation in shed A was not strictly comparable with the earlier years since the incidence of salmonella infection was lower, and in one batch, a serotype other than *S. typhimurium*, namely *S. newport*, was isolated. The reason for the lower incidence was not established although it may reflect either (1) a change in the purchasing pattern of calves since fewer calves originated from Wales and more from the S.W. of England in 1983 (Table 1), or (2) a reduction in the risk of aerosol spread of infection since, following our suggestion, the daily hosing of the floors in shed A was discontinued in the autumn of 1982.

Table 2. *Excretion of* Salmonella typhimurium *by calves in batch* 18

Calf ref.	Days on the farm																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
18/1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	.	.	+	+	+	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	+	.	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
6	+	.	.	.	.	+	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	+*	+	+	+	+	.	+	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
8	.	.	+	.	.	+	+	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	+	.	.	.	.	.	.	.	+	+
11	+	.	.	.	+	+	+	.	+	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.
12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
14	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

+, Excretion of *S. typhimurium* * Treated with oral antibacterial drugs

Table 3. *Excretion of* Salmonella typhimurium *by calves in batch* 21

Calf ref.	Days on the farm																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
21/1	*	*	.	.	.	+	+	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	+	+	.	+	+	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
3	.	.	.	.	.	.	+	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	.	.	.	.	+	+*	.	*	.	.	.	*	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.
5	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.
6	.	.	+	+	+*	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
7	.	.	.	.	.	+	+*	+	.	.	+	+	+	+	+	+	+	.	.	.	+	.	.	.	.	.	.	.
8	.	.	.	.	*	+	+	+	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+*	+	+	.	.	.	.	.	.	.	.	.	.
10	.	.	+	+	+	+*	+*	+*	+	+	+	+	+	+	+	+	+*	+*	+*	+	+	.	.	.	.	.	.	.	.
11	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	+
12	.	.	+	+*	+*	+	+	+	+	+	+	+	+	+	+*	+*	+	+	+	.	.	.	.	.	.	.	.	.
13	.	.	+	+*	+	+	+	+	+	+	.	*	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.
14	.	.	.	.	+	+	+	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
15	.	.	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16	.	.	+	+	+	+	+	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+
17	.	.	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
18	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.

+, Excretion of *S. typhimurium* * Treated with oral antibacterial drugs

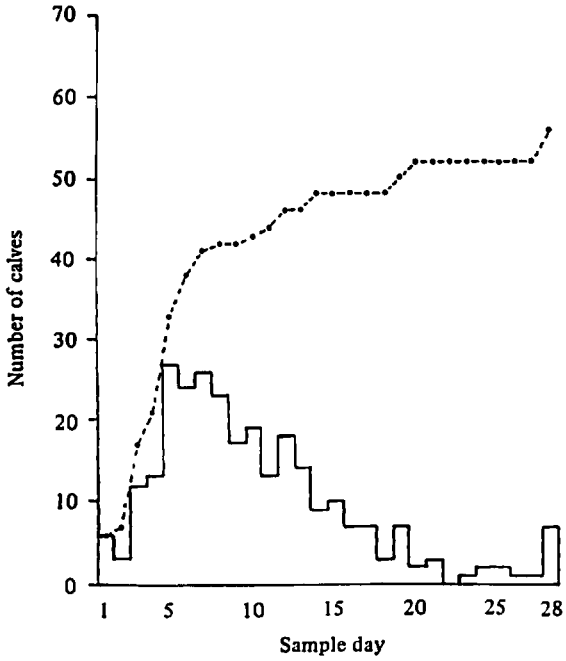

Fig. 2. The number of calves, reared in five batches in 1983, excreting salmonella on each day of a 28-day rearing period together with the cumulative total of excreting animals (●--●).

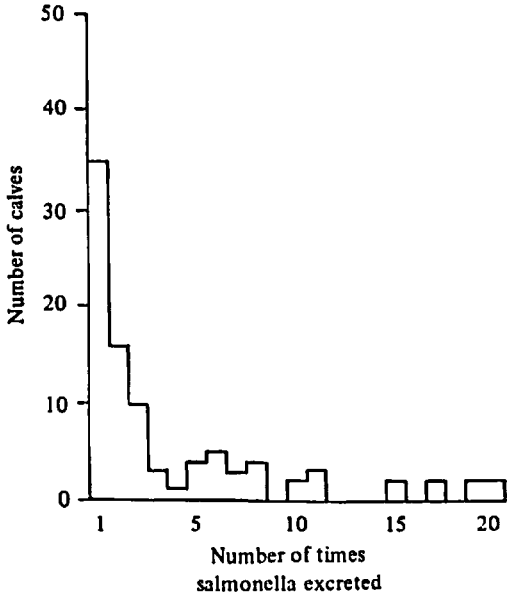

Fig. 3. The number of days on which 90 calves, reared in five batches in 1983, excreted salmonella during a 28 day rearing period.

This study confirmed that relatively few market calves were excreting salmonella on arrival on the farm. It is probable that these animals contracted infection either on their farm of origin, or in the market or markets through which they passed, or from the lorry or lorries in which they were transported. *S. newport*, a serotype

https://doi.org/10.1017/S0022172400065116 Published online by Cambridge University Press

which had not been isolated by us previously in this farm (Linton, Timoney & Hinton, 1981; Hinton & Linton, 1982; Hinton *et al.* 1983 and unpublished observations) was probably contracted from one of these sources since in three of the four excretors it was first isolated within three days of their arrival on the farm.

The majority of infections were first demonstrated during the first 3–7 days residence on the farm however, and this suggests that, despite thorough cleansing of the rooms in which the animals were placed, the farm environment was acting as an important source of infection. Support for this hypothesis was obtained from batches 19 and 21. In batch 19, 7 of the 11 excretors were all positive for the first time on the fifth day while in batch 21 no calves were positive on the first 2 days, while seven excreted on the third.

In the majority of animals salmonella excretion remained subclinical despite the fact that *S. typhimurium* phage type DT204c is pathogenic for calves and adult cattle. A relatively high proportion of excretors were positive on less than four occasions. These animals were probably exposed to relatively small numbers of salmonella organisms, and as excretion was transient they can only play a minor role in the maintenance and spread of salmonella infections on the farm. The situation was obviously different for the other infected animals since excretion must have been an active process, with some calves excreting for 2 or 3 weeks. Despite these relatively long periods of excretion the infections were generally self-limiting. This phenomenon has also been demonstrated in young chickens with natural subclinical salmonella infections (Linton, Al-Chalaby and Hinton, in press). However, it has yet to be established whether the reduction of infection rate with time in both calves and chicks is a consequence of the development of either the animal's immune system or its intestinal microflora or to some other factors as yet unidentified. The answer to these questions will require additional detailed studies of individual animals and when obtained they may indicate the way in which the successful control of salmonella infections in young farm livestock can be achieved.

We are grateful to the AFRC for financial support. One of us (I.O.S.) was in receipt of a British Council Technical Cooperation Training Award. We would like to thank Professor F. J. Bourne for the provision of facilities and Mrs R. Hinton and Mrs P. Parsons for additional technical assistance.

REFERENCES

HINTON, M., ALI, E. A., ALLEN, V. & LINTON, A. H. (1983). The excretion of *Salmonella typhimurium* in the faeces of calves fed milk substitute diet. *Journal of Hygiene* **91**, 33–45.

HINTON, M. & LINTON, A. H. (1982). The survival of multi-antibacterial drug-resistant *Escherichia coli* and *Salmonella typhimurium* in stored static slurry from a veal calf unit. *Journal of Hygiene* **88**, 557–565.

LINTON, A. H., AL-CHALABY, Z. A. M. & HINTON, M. (1984). Natural subclinical *Salmonella* infection in chickens: a potential model for testing the effects of various procedures on *Salmonella* shedding. *Veterinary Record*, In press.

LINTON, A. H., TIMONEY, J. F. & HINTON, M. (1981). The ecology of chloramphenicol resistance in *Salmonella typhimurium* and *Escherichia coli* in calves with endemic salmonella infection. *Journal of Applied Bacteriology* **50**, 115–129.