J. Hyg., Camb. (1980), **84**, 137
Printed in Great Britain

Further observations on the effect of feeding diets containing avoparcin, bacitracin and sodium arsenilate on the colonization of the alimentary tract of poultry by salmonella organisms

By H. WILLIAMS SMITH and J. F. TUCKER
Houghton Poultry Research Station,
Houghton, Huntingdon, Cambs. PE17 2DA

(*Received* 2 *July* 1979)

The continuous administration of food containing 10 mg/kg of avoparcin to groups of 28 chickens in contact with five chickens experimentally infected with a nalidixic acid-resistant (*nal*^{r}) mutant of a salmonella strain strongly favoured the colonization of their alimentary tracts with salmonella organisms. Bacitracin, 10 mg/kg, either had no effect or only slightly favoured salmonella colonization and sodium arsenilate usually hindered it.

These results were obtained with four different strains of chickens, four different diets and five salmonella serotypes, including a *nal*^{s} form of one of them; the chickens were kept both on wire-netting and littered floors. Similar results were also obtained when turkeys were used instead of chickens.

When groups of 33 chickens were inoculated orally with different doses of *nal*^{r} *Salmonella typhimurium* organisms, smaller doses were required to infect those fed on an avoparcin-containing diet than those fed on a non-medicated diet. Infection spread more rapidly and more extensively through the avoparcin-fed groups than through the non-medicated groups.

INTRODUCTION

Smith & Tucker (1975*a*, *b*, 1978) found that the feeding of diets containing some of the additives that are commercially available for growth promotion and other purposes facilitated the colonization of the alimentary tract of chickens by *Salmonella typhimurium* organisms which they, or chickens with which they were in contact, had been given orally. Generally similar results were reported by Kobland & Gustafsen (1977). In the experiments performed by Smith & Tucker, only one strain of *S. typhimurium* was studied. This was a nalidixic acid-resistant mutant, used because it enabled the numbers of salmonella organisms in faeces to be counted. The chickens were of one strain fed on the same basal diet and kept on wire-netting floors. Because of this, and because chickens are usually regarded as the main source of the salmonella organisms that cause food poisoning in man, it was decided to broaden these studies in order to determine whether their results have a general application. This was done by studying the effect of additives when they were incorporated in four different poultry feeds and given to four strains of chickens and one strain of turkeys kept on wire-netting or littered floors

0022–1724/80/0059–1979 $01.00

and exposed to infection with one or other of five antigenically different strains of *Salmonella* and to a nalidixic acid-sensitive form of the *S. typhimurium* strain used in the earlier experiments; the results are reported in this paper. To reduce the work load, only three of the additives previously studied were used, one, avoparcin, that had strongly promoted *S. typhimurium* colonization, one, bacitracin, that had slightly promoted it and one, sodium arsenilate, that had usually hindered it. They were fed at only one concentration, a concentration commonly used commercially. With one exception, the experiments were restricted to those in which only five birds in each group of 33 were actually inoculated with salmonella organisms; in the exceptional experiment, all the chickens in each group were given them.

MATERIALS AND METHODS

Experimental animals

Four different strains of chickens from salmonella-free flocks were used. These comprised a commercial broiler hybrid (CBH) and one strain each of the Rhode Island Red (RIR), White Leghorn (WL) and Light Sussex (LS) breeds, the latter strain being the one used in the earlier experiments. The turkeys were a commercial hybrid.

Salmonella *strains*

The strain of *S. typhimurium* (O 1, 4, 5, 12: H i; 1, 2) previously used as a nalidixic acid-resistant (*nal*^{r}) mutant was now also used in its nalidixic acid-sensitive (*nal*^{s}) form. Four other strains were used as spontaneous *nal*^{r} mutants, one of *Salmonella heidelberg* (O 1, 4, 5, 12:H r; 1, 2), one of *Salmonella oranienburg* (O 6, 7:H m, t:–), one of *Salmonella infantis* (O 6, 7:H r; 1, 5) and one of *Salmonella senftenberg* (O 1, 3, 19:H g, s, t;–). The five strains had been isolated from chickens.

Diets

Three of the diets that were used, 1, 2 and 3, had been manufactured by different large national feed compounders for feeding to growing chickens; the fourth, SM, prepared at this station was the one used in earlier experiments (Smith & Tucker, 1975*a*). None of the four diets contained antimicrobial substances. As required, bacitracin (10 mg/kg), avoparcin (10 mg/kg) and sodium arsenilate (250 mg/kg) were added to them as pre-mixes. These medicated diets were fed continuously to chickens and turkeys from the time they were hatched.

The management of the experimental animals and the method of orally infecting five in each group of 33 when 4 days old with approximately 3×10^{8} viable salmonella organisms was exactly as described previously (Smith & Tucker, 1975*a*, *b*, 1978). Chickens and turkeys infected at this age do not become unwell. The method of assessing the concentration of *nal*^{r} salmonella organisms in the faeces and caecal contents of the experimentally infected and the in-contact animals in each group has also been described. It depends on specimens being inoculated in a standard manner onto plates of brilliant green agar containing sodium nalidixate and novobiocin – very few faecal bacteria grow on this medium and the colonies

of those that do can easily be differentiated visually from those of the infecting salmonella strain. In experiments in which the *nal*^{s} form of the *S. typhimurium* was used, it was not possible to count the numbers of salmonella organisms in faeces and caecal contents because a suitable solid culture medium was not available. Accordingly, these specimens were examined by enrichment in selenite broth for 24 h at 37 °C. followed by culture on deoxycholate-citrate-agar for 24 h at 37 °C.; they were recorded as positive or negative for the presence of salmonella organisms. Unless stated, chickens of the LS strain kept on wire-netting floors, fed on the SM diet and exposed to infection with the *nal*^{r} *S. typhimurium* strain were used in all experiments. Experiments were usually concluded after 50 days, the time at which broiler chickens are usually slaughtered.

RESULTS

The faecal excretion of Salmonella heidelberg, infantis, oranienburg *and* senftenberg *by chickens fed on additive-containing SM diet*

The results of examining the faeces and caecal contents of groups of 28 chickens fed continuously on the SM diet containing avoparcin, bacitracin or sodium arsenilate while in contact with five chickens experimentally infected with a sodium nalidixate-resistant (*nal*^{r}) mutant of *Salmonella heidelberg*, *infantis*, *oranienburg* or *senftenberg* are summarized in Tables 1, 2 and 3.

Organisms of all four salmonella strains were isolated more often and in higher concentration from the faeces of the groups of chickens fed on the diet containing avoparcin than from the faeces of the groups fed on the non-medicated diet. The infections that developed in the avoparcin-fed groups, too, persisted much longer than those that developed in the non-medicated groups. A high proportion of the chickens in the former groups, but not in the latter groups, were still heavily infected at 50 days when the experiments were concluded; the difference was particularly noticeable when the results of the caecal examinations were compared. The percentage of avoparcin-fed chickens that became infected with *S. heidelberg*, *infantis*, *oranienburg* or *senftenberg* at some time during the course of the experiment was 100, 100, 100 and 96 respectively. The corresponding figures for the chickens fed on the non-medicated diet were 14, 21, 21 and 18 respectively.

There was little or no difference in the rate and amount of faecal excretion of organisms of the four salmonella strains between the chickens fed on the bacitracin-containing diet and those fed on the non-medicated diet. In this experiment, organisms of all four salmonella strains spread more extensively amongst the chickens fed on the non-medicated diet than in the similarly fed chickens in the avoparcin experiments; the infections in these non-medicated chickens, though, were usually light and only a few persisted to the end of the experiment. The percentage of the chickens given the bacitracin-containing diet that became infected with *S. heidelberg*, *infantis*, *oranienburg* and *senftenberg* was 100, 100, 82 and 71 respectively; the corresponding figures for the chickens fed on the non-medicated diets were 89, 100, 86 and 71 respectively.

Organisms of *S. heidelberg*, *infantis* and *oranienburg* were usually isolated less

Table 1. *The isolation of* Salmonella heidelberg, inantis, oranienburg *and* senftenberg *from the faeces of groups of 28 chickens in contact with five chickens infected with these organisms and fed on the SM diet containing avoparcin*

Time* (days)	% of chickens from which salmonella organisms were isolated following exposure to infection with											
	S. heidelberg				*S. infantis*				*S. oranienburg*				*S. senftenberg*			
	Avoparcin-fed		Non-medicated		Avoparcin-fed		Non-medicated		Avoparcin-fed		Non-medicated		Avoparcin-fed		Non-medicated	
	†>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T
3	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
7	11	25	0	4	0	21	0	4	4	29	0	0	0	11	0	0
10	32	54	0	4	25	61	0	4	4	32	0	0	0	21	0	4
16	71	93	0	11	32	93	0	18	79	93	0	11	32	71	0	7
23	75	79	0	11	25	93	0	7	32	100	0	18	18	79	0	4
30	54	96	0	4	46	100	0	4	57	96	0	7	29	79	0	0
37	36	100	0	0	18	100	0	4	7	100	0	4	11	96	0	0
44	50	96	0	4	29	93	0	4	25	96	0	4	29	96	0	0
50	50	82	0	4	25	71	0	0	36	93	4	4	36	93	0	0
50 (caeca)‡	93	93	0	14	79	93	0	4	82	82	0	21	93	93	0	0

* After the five chickens were infected with *nal*^{r} forms of the salmonella strains when 4 days old and in contact with the 28 non-infected chickens; avoparcin, 10 mg/kg, of the SM diet, was given from day 1.

† >50 = >50 salmonella colonies grew on the culture plate; T = salmonella organisms isolated by selenite enrichment or direct culture.

‡ Results of examining caecal contents when the chickens were killed at the end of the experiment (50 days).

Table 2. *The isolation of* Salmonella heidelberg, infantis, oranienburg *and* senftenberg *from the faeces of groups of 28 chickens in contact with five chickens infected with these organisms and fed on the SM diet containing bacitracin*

	% of chickens from which salmonella organisms were isolated following exposure to infection with											
	S. heidelberg				*S. infantis*				*S. oranienburg*			
	Bacitracin-fed		Non-medicated		Bacitracin-fed		Non-medicated		Bacitracin-fed		Non-medicated	
Time (days)	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T
3	0	7	0	14	0	21	7	21	0	0	0	0
7	7	36	18	61	18	89	29	71	4	29	0	39
10	11	68	7	71	43	82	21	86	7	25	7	43
16	18	96	18	71	46	93	29	100	18	75	7	57
23	7	57	7	57	11	75	7	54	11	43	4	57
30	0	36	4	36	4	50	0	36	0	18	0	32
37	0	36	0	21	0	18	0	21	0	21	0	32
44	0	44	0	11	0	14	0	18	0	7	0	14
50	0	4	0	0	0	11	0	21	0	7	0	11
50 (caeca)	0	4	0	0	0	4	0	14	0	7	0	14

	S. senftenberg			
	Bacitracin-fed		Non-medicated	
Time (days)	> 50	T	> 50	T
3	0	18	0	7
7	7	36	0	14
10	11	71	4	18
16	7	89	11	50
23	7	32	14	54
30	4	14	7	43
37	0	21	4	25
44	0	18	4	14
50	0	21	4	14
50 (caeca)	4	25	0	7

The bacitracin, 10 mg/kg, of the SM diet, was given from day 1.
For other details and abbreviations, see Table 1.

Table 3. *The isolation of* Salmonella heidelberg, infantis, oranienburg *and* senftenberg *from the faeces of groups of* 28 *chickens in contact with five chickens infected with these organisms and fed on the SM diet containing sodium arsenilate*

Time (days)	% of chickens from which salmonella organisms were isolated following exposure to infection with															
	S. heidelberg				*S. infantis*				*S. oranienburg*				*S. senftenberg*			
	Arsenilate-fed		Non-medicated		Arsenilate-fed		Non-medicated		Arsenilate-fed		Non-medicated		Arsenilate-fed		Non-medicated	
	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T	> 50	T
3	0	0	0	4	0	0	0	14	0	0	0	14	0	0	0	4
7	0	0	7	43	0	0	11	75	0	0	7	29	0	0	4	21
10	0	0	7	50	0	0	7	89	0	0	0	29	0	0	4	29
16	7	21	4	43	0	0	18	93	7	11	0	46	0	11	4	21
23	14	29	7	18	0	11	7	79	0	0	11	36	4	21	0	14
30	7	25	0	7	0	11	4	39	0	0	0	25	0	18	0	14
37	0	14	0	0	0	11	0	25	0	0	0	18	4	14	0	7
44	4	7	0	0	0	7	0	25	0	0	0	7	0	7	0	0
50	0	4	0	0	0	0	0	18	0	0	0	4	0	4	0	0
50 (caeca)	0	14	0	0	0	4	0	14	0	0	0	14	4	14	0	0

The sodium arsenilate, 250 mg/kg, of the SM diet, was given from day 1.
For other details and abbreviations, see Table 1.

frequently from the faeces of the chickens fed on the sodium arsenilate-containing diet than from the faeces of those fed on the non-medicated diet; this difference was not noted in the case of the chickens exposed to infection with *S. senftenberg*. The percentage of the chickens given the arsenilate-containing diet that became infected with *S. heidelberg, infantis, oranienburg* or *senftenberg* was 39, 21, 14 and 39 respectively. The corresponding figures for the chickens fed on the non-medicated diet were 79, 86, 61 and 64 respectively. The infection spread more slowly through the groups of chickens fed on the arsenilate-containing diet than through the groups fed on the non-medicated diet; no spread at all was detected in any of the former groups within 16 days of exposure.

When the above experiments were repeated with the *nal*^{s} parent strain of the *nal*^{r} *S. typhimurium* mutant used in the earlier experiments, the percentage of the 28 chickens in a group fed on the avoparcin-containing diet that were found to be excreting organisms of this strain in their faeces, 3, 7, 10, 16, 23, 30, 37, 44 and 50 days after exposure was 11, 21, 68, 93, 96, 89, 89, 68 and 61 respectively. The corresponding figures for the group fed on the bacitracin-containing diet was 4, 11, 21, 32, 36, 32, 32 and 11 respectively, for the group fed on the arsenilate-containing diet was 0, 4, 14, 21, 18, 14, 7, 11 and 0 respectively and for the group fed on the non-medicated diet was 4, 7, 14, 25, 21, 7, 7, 4 and 0 respectively. At the end of the experiment (50 days), the percentage of the avoparcin-fed, bacitracin-fed, arsenilate-fed and non-medicated chickens found to have organisms of the *S. typhimurium* strain in their caeca was 82, 29, 0 and 0 respectively. When the experiment was repeated, similar results were obtained.

The faecal excretion of Salmonella typhimurium *by chickens of different strains and by turkeys fed on additive-containing SM diet*

The results of examining the faeces and caecal contents of groups of 28 White Leghorn (WL), Rhode Island Red (RIR) and commercial broiler hybrid (CHB) chickens fed continuously on the SM diet containing avoparcin, bacitracin or sodium arsenilate while in contact with five chickens experimentally infected with the *nal*^{r} *S. typhimurium* strain is summarized in Table 4. The infection spread more rapidly through the groups of WL, RIR and CBH chickens fed on the avoparcin-containing diets than it did through the corresponding groups fed on the non-medicated diet. Moreover, the infections that developed in the avoparcin-fed chickens of all three strains was heavier and persisted for much longer than it did in the chickens fed on the non-medicated diet. A high proportion of the avoparcin-fed chickens were still excreting high concentrations of *S. typhimurium* organisms in their faeces at the conclusion of the experiment, whereas all except one or two of those fed on the non-medicated diet were free of faecal infection at this time; the caecal contents of the avoparcin-fed chickens were even more heavily infected than the faeces. By contrast, the course of the infection in the bacitracin-fed chickens of each strain was little different from that in the chickens of the corresponding strain fed on the non-medicated diet. In general, the infections that developed in the arsenilate-fed chickens of each strain were lighter and less numerous than those that developed in the chickens of the corresponding strain fed on

Table 4. *The isolation of* Salmonella typhimurium *from the faeces of groups of* 28 *chickens of different strains in contact with five chickens infected with these organisms and fed on the SM diet containing different additives*

	% of chickens from which *S. typhimurium* organisms were isolated															
	White Leghorns fed on a diet containing								Rhode Island Reds fed on a diet containing							
	Avoparcin		Bacitracin		Arsenilate		No additives		Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T
3	18	46	11	25	0	0	0	7	0	4	4	7	0	0	0	0
7	54	68	36	82	0	7	18	39	18	21	4	18	0	7	0	4
10	82	86	39	86	0	7	21	61	14	29	7	14	0	7	0	7
16	50	82	14	96	7	18	29	86	29	75	4	14	4	7	4	14
23	46	75	21	68	11	14	18	61	54	71	4	14	0	7	0	0
30	18	50	4	32	4	14	4	25	21	79	4	14	0	4	0	7
37	32	57	0	7	4	11	4	11	25	68	0	7	0	7	0	7
44	21	46	0	11	0	4	4	4	18	68	0	4	0	0	0	14
50	29	50	0	0	0	0	0	4	36	54	0	4	0	0	0	4
50 (caeca)	64	82	4	4	0	0	0	4	75	89	0	4	0	0	0	11

	Commercial broiler hybrids fed on a diet containing							
	Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T
3	0	4	0	29	0	4	0	4
7	18	54	25	71	4	4	11	32
10	11	43	21	61	0	7	14	36
16	11	57	4	50	0	14	7	29
23	32	54	4	39	0	14	4	36
30	7	36	0	25	0	11	0	21
37	4	29	0	18	0	0	0	11
44	0	18	0	0	0	0	0	7
50	7	14	0	4	0	0	0	7
50 (caeca)	14	28	0	0	0	0	0	7

For details and abbreviations, see Table 1.

the non-medicated diet. Similar results were obtained when the above experiment was repeated, using turkeys instead of chickens with the exception that the infections that developed in the avoparcin-fed turkeys did not persist for as long as they did in the avoparcin-fed chickens. The percentage of avoparcin-fed turkeys whose faeces and caecal contents were still infected when the experiment was concluded at 50 days was 11 and 14 respectively; the corresponding figures for the turkeys fed on the non-medicated diet was 0 and 4 respectively. The actual percentage of turkeys that became infected in the avoparcin, bacitracin and sodium arsenilate-fed groups and the group given non-medicated food was 86, 46, 39 and 64 respectively.

Two additional experiments were performed in CBH chickens in which only the avoparcin-containing diets were compared with non-medicated diets. The results of one were similar to those illustrated in Table 4. The infections that developed in the chickens in the avoparcin-fed group in the other experiment were much heavier and more persistent than in the one shown in the table – salmonella organisms were isolated from the caeca of 86% of the chickens in this group compared with 14% in the corresponding non-medicated group.

The faecal excretion of Salmonella typhimurium *by chickens fed on different commercial diets containing the additives*

The results of examining the faeces and caecal contents of groups of 28 chickens in contact with five chickens experimentally infected with the *nal*^{r} *S. typhimurium* strain and fed continuously on one or the other of three commercially available diets in which had been incorporated avoparcin, bacitracin or sodium arsenilate is summarized in Table 5. The infections that developed in the chickens fed on all three commercial diets containing avoparcin were heavier and more persistent than those in the chickens fed on the corresponding non-medicated diets. Those that developed in the chickens fed on the three diets containing bacitracin were slightly heavier and slightly more persistent than those in the chickens fed on the corresponding non-medicated diets. The few infections that developed in the chickens fed on arsenilate-containing diets 1 and 3 were more transient and lighter than those that developed in the chickens fed on the corresponding non-medicated diets; as far as diet 2 was concerned, there was little difference between the results for the arsenilate-fed chickens and the non-medicated chickens. The percentage of chickens fed on avoparcin, bacitracin, arsenilate-containing or non-medicated diet No. 1 that became infected was 100, 61, 7 and 46 respectively. The corresponding figures for diet No. 2 were 89, 54, 18 and 25 respectively, and for diet No. 3 were 64, 36, 7 and 25 respectively. Because *S. typhimurium* organisms persisted in the alimentary tract of the chickens fed on the four forms of diet No. 3 for a shorter period of time than in the alimentary tract of the chickens fed on the corresponding forms of the other two diets, the experiments with this diet were repeated three times. Similar results were obtained to those shown in Table 5, except that the infections that developed in the chickens in the three avoparcin-fed groups were heavier and more persistent. The percentage of chickens in these three groups that were excreting salmonella organisms in their faeces at 50 days

Table 5. *The isolation of* Salmonella typhimurium *from the faeces of groups of* 28 *chickens in contact with five chickens infected with these organisms and fed on different commercial diets containing additives*

	% of chickens from which *S. typhimurium* organisms were isolated when fed on commercial diet															
	No. 1 containing								No. 2 containing							
	Avoparcin		Bacitracin		Arsenilate		No additives		Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T
3	0	0	0	0	0	11	0	0	0	4	0	4	0	0	0	0
7	29	64	0	7	0	18	4	21	7	32	7	18	4	7	4	14
10	39	61	4	18	0	0	7	25	7	36	7	36	0	14	0	14
16	21	75	14	21	0	0	11	29	21	57	0	36	0	4	0	11
23	29	96	4	43	0	0	0	0	21	43	0	4	4	4	0	0
30	18	86	0	18	0	0	0	0	36	64	0	4	0	4	0	4
37	46	79	7	11	0	0	0	0	14	46	0	0	0	4	0	0
44	39	89	0	7	0	0	0	0	4	43	0	4	0	0	0	0
50	21	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50 (caeca)	14	29	0	0	0	0	0	4	4	7	0	0	0	0	0	0

	No. 3 containing							
	Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T
3	0	7	0	0	0	0	0	11
7	36	50	11	21	0	0	0	18
10	21	43	0	14	0	4	0	0
16	7	46	4	18	0	0	0	0
23	0	18	0	7	0	0	0	0
30	0	4	0	0	0	4	0	0
37	0	4	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0
50 (caeca)	0	4	0	0	0	0	0	0

For other details and abbreviations, see Table 1.

when the experiment was terminated was 50, 14 and 14; no faecal excreters were found in the non-medicated groups after 23 days. The percentage of chickens that became infected in the three avoparcin-fed groups was 96, 96 and 75, in the bacitracin-fed groups was 46, 25 and 25, in the arsenilate-fed groups was 4, 0 and 0 in the non-medicated groups was 25, 14 and 11.

The faecal excretion of Salmonella typhimurium *by chickens kept on litter and fed on additive-containing SM diet*

The results of examining the faeces and caecal contents of groups of 28 Light Sussex (LS), White Leghorn (WL) and Rhode Island Red (RIR) chickens fed continuously on the SM diet containing avoparcin, bacitracin or sodium arsenilate while in contact with five chickens infected with the *nal*^{r} *S. typhimurium* strain is summarized in Table 6; unlike the chickens used in the previous experiments, all those used in this experiment were kept on deep litter consisting of wood shavings. Salmonella organisms were isolated more often and in higher concentration from the faeces of all three strains of chickens fed on the avoparcin-containing diet than they were from the corresponding chickens fed on the non-medicated diet and the infections that developed in the avoparcin fed chickens usually persisted longer than they did in the non-medicated ones. In the groups of LS and WL chickens, the course of the infection was similar in the bacitracin-fed chickens to that in the non-medicated ones but in the RIR chickens the incidence of infection found at each examination was usually lower in the bacitracin-fed chickens than in the non-medicated ones. In all three strains of chickens it was usually lower in the arsenilate-fed groups than in the non-medicated groups. In general, the spread of infection was less extensive in the LS chickens than in the WL and RIR chickens. The percentage of avoparcin-fed, bacitracin-fed, arsenilate-fed and non-medicated LS chickens that became infected was 89, 36, 0 and 14 respectively. The corresponding figures for the WL and RIR chickens were 97, 90, 76 and 93 and 100, 52, 34 and 83 respectively.

The above experiment was repeated in two groups of the commercial hybrid strain, one group being given the avoparcin-containing diet and one the non-medicated diet. The results were similar to those shown in Table 6 for the RIR strain.

The faecal excretion of Salmonella typhimurium *by chickens fed on avoparcin-containing SM diet and inoculated orally with different numbers of these organisms*

The results of examining the faeces of groups of 33 chickens fed continuously on an avoparcin-containing or a non-medicated SM diet and inoculated orally with different numbers of viable organisms of the *nal*^{r} *S. typhimurium* strain when 4 days old, is summarized in Table 7; all the groups were kept on litter. *S. typhimurium* was never isolated from the faeces of any of the avoparcin-fed or non-medicated chickens inoculated with 10^{2} organisms or of any of the non-medicated ones inoculated with 10^{3} organisms. At each examination of the chickens in the other groups, they were usually found more frequently and in greater concentration in the faeces of the chickens in the avoparcin-fed group than in the faeces

Table 6. *The isolation of* Salmonella typhimurium *from the faeces of 28 chickens of different breeds kept on deep litter with five chickens infected with these organisms and fed on the SM diet containing different additives*

	% of chickens from which *S. typhimurium* organisms were isolated															
	Light Sussex fed on								White Leghorns fed on							
	Avoparcin		Bacitracin		Arsenilate		No additives		Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T	>50	T
4	0	4	0	0	0	0	0	0	18	54	0	21	0	21	4	18
8	0	7	7	11	0	0	0	0	11	71	7	39	4	18	25	57
11	7	21	4	11	0	0	0	7	43	93	18	68	18	46	50	68
18	21	64	4	14	0	0	0	7	32	79	0	54	11	29	14	54
25	29	75	4	14	0	0	0	4	43	100	18	50	14	36	18	54
32	32	79	0	11	0	0	0	0	14	64	4	21	18	39	4	14
38	0	25	4	18	0	0	0	0	25	51	0	14	11	25	0	4
45	4	11	0	7	0	0	0	4	18	50	0	0	11	21	0	7
51	4	4	0	4	0	0	0	0	0	46	0	18	0	4	0	11
51 (caeca)	4	11	0	4	0	4	0	0	32	75	0	25	18	21	0	18

	Rhode Island Reds fed on							
	Avoparcin		Bacitracin		Arsenilate		No additives	
Time (days)	>50	T	>50	T	>50	T	>50	T
4	0	4	0	4	0	4	0	7
8	36	57	0	7	4	11	4	4
11	43	57	0	4	7	14	4	7
18	25	71	0	11	7	21	7	32
25	50	79	0	4	4	25	29	57
32	29	71	0	4	11	18	14	68
38	21	64	0	11	7	7	0	14
45	18	50	0	18	0	7	0	7
51	4	57	0	14	0	4	0	11
51 (caeca)	11	61	7	32	0	7	0	4

The litter consisted of wood shavings.
For other details and abbreviations see Table 1.

Table 7. *The isolation of* Salmonella typhimurium *from the faeces of groups of* 33 *chickens inoculated orally with different viable numbers of these organisms and fed on the SM diet containing avoparcin*

	% of chickens from which *S. typhimurium* organisms were isolated following inoculation with							
	10^2 organisms		10^3 organisms		10^4 organisms		10^5 organisms	
	Avoparcin-fed	Non-medicated	Avoparcin-fed	Non-medicated	Avoparcin-fed	Non-medicated	Avoparcin-fed	Non-medicated
Time (days)	>50 T	>50 T	>50 T	>50 T	>50 T	>50 T	>50 T	>50 T
4	0 0	0 0	0 0	0 0	0 3	0 3	3 9	0 0
8	0 0	0 0	3 3	0 0	6 18	0 6	9 15	0 0
10	0 0	0 0	3 6	0 0	3 9	0 6	9 12	0 3
18	0 0	0 0	3 9	0 0	6 21	3 12	15 30	0 3
24	0 0	0 0	18 27	0 0	33 61	3 21	30 64	3 9
31	0 0	0 0	6 36	0 0	6 39	6 21	15 73	6 15
38	0 0	0 0	3 15	0 0	3 33	0 18	12 45	0 15
45	0 0	0 0	0 9	0 0	0 6	0 3	0 24	0 12
51	0 0	0 0	0 9	0 0	0 6	0 0	3 9	0 12
57	0 0	0 0	0 0	0 0	0 12	0 0	0 9	0 3
57 (caeca)	0 0	0 0	3 3	0 0	0 0	0 0	3 9	0 3

All the groups of chickens were kept on litter.
For other details and abbreviations, see Table 1.

the chickens in the corresponding non-medicated group. The percentage of avoparcin-fed chickens inoculated with 10^2, 10^3, 10^4 and 10^5 organisms that became infected was 0, 48, 91 and 94 respectively. The corresponding figures for the non-medicated chickens was 0, 0, 42 and 39 respectively.

DISCUSSION

In earlier studies (Smith & Tucker, 1975*b*, 1978) it was shown that some agents such as avoparcin, nitrovin, tylosin and lincomycin profoundly favoured the colonization of the alimentary tract of chickens with salmonella organisms and it was reasoned that, because of the importance of chickens as a source of salmonellas that cause food poisoning in man, their use as feed additives for poultry should be discouraged. It was pointed out, though, that because the studies were performed with one strain of salmonella in one strain of chicken fed on one diet, different results might have been obtained under other conditions. The results of the present study using an additional five strains of *Salmonella* including a sodium-nalidixate-sensitive one, an additional three diets and an additional three strains of chickens and one strain of turkey, suggest that the findings of the earlier studies have general application and therefore add considerable weight to the conclusions drawn from that study; so do the results of the experiments in which the chickens were kept on littered instead of wire-netting floors and of the experiments with avoparcin in which all the chickens in the groups were inoculated with comparatively low numbers of organisms. The results of all the experiments also confirm that bacitracin, at the most, only slightly favours salmonella colonization of the alimentary tract and that sodium arsenilate usually hinders it. It seems reasonable, then, that substances like these should be used as feed additives for growth promotion rather than substances like avoparcin that strongly promote salmonella colonization.

We are grateful to Mrs Joan Simpson, Mrs Jill Burt and Miss Margaret Lovell for their capable technical help. Our thanks are also due to Dr P. M. Biggs, Mrs Wendy Bruce and Mrs Sylvia Lewin for assistance in a variety of ways.

REFERENCES

Kobland, J. D. & Gustafson, R. H. (1977). The influence of feed antibiotics on the spread of salmonella in chicks. *Proceedings of the 17th Inter-science Conference on Antimicrobial Agents and Chemotherapy sponsored by the American Society for Microbiology*, 12th–14th October 1977. New York, 106.

Smith, H. Williams & Tucker, J. F. (1975*a*). The effect of antibiotic therapy on the faecal excretion of *Salmonella typhimurium* by infected chickens. *Journal of Hygiene* **75**, 275–92.

Smith, H. Williams & Tucker, J. F. (1975*b*). The effect of feeding diets containing permitted antibiotics on the faecal excretion of *Salmonella typhimurium* by experimentally infected chickens. *Journal of Hygiene* **75**, 239–310.

Smith, H. Williams & Tucker, J. F. (1978). The effect of antimicrobial feed additives on the colonization of the alimentary tract of chickens by *Salmonella typhimurium*. *Journal of Hygiene* **80**, 217–31.