Flock Infection and Transport as Sources of Salmonellae in Broiler Chickens and Carcasses

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ABSTRACT

Cultural monitoring was used to determine the incidence and sources of salmonellae in a 4160-bird broiler flock raised on litter in 32 pens. Twenty-five of the pens remained apparently free of salmonellae during the 49-day growing period. Salmonella johannesburg, first detected in the meat meal component of the starter ration, was recovered from the litter of seven pens and from the intestines of dead or culled chicks from two pens. Salmonella alachua was also recovered from two of these pens.

Culture of swabs collected from the plastic crates used to transport this flock for processing showed that 97/112 (86.6%) were contaminated with salmonellae (15 serovars) before the birds were loaded. The crate washer at the plant did not remove salmonellae from these crates: 97/132 (73.5%) crates sampled after washing yielded salmonellae. Eleven serovars were recovered, including S. johannesburg and S. alachua introduced by the infected flock.

Twelve of 31 chickens (38.7%) collected when the birds were unloaded at the processing plant were intestinal carriers of S. johannesburg and/or S. alachua and 29 (93.5%) were external carriers. Salmonella johannesburg, S. alachua and four other serovars were isolated from the feathers of these birds.

Eleven of 25 (44%) carcasses tested from this flock yielded salmonellae. Salmonella johannesburg or S. alachua, first isolated from the infected flock, were recovered from five carcasses and S. haardt and S. typhimurium, first isolated from the transport crates, were recovered from six carcasses.

RÉSUMÉ

Cette étude consistait à recourir à des examens bactériologiques périodiques visant à déterminer l'incidence et l'origine des salmonelles, dans un troupeau qui comptait 4160 poulets de gril gardés dans 32 parcs pourvus de litière. Vingt-cinq de ces parcs demeurèrent apparemment exempts de salmonelles, tout au long des 49 jours sur lesquels s'échelonna la période de croissance. On isola Salmonella johannesburg, d'abord de la farine de viande utilisée dans la moulée de début, puis de la litière de sept parcs et des intestins des poulets qui moururent ou qu'il fallut éliminer de deux parcs; on isola aussi Salmonella alachua de la litière de deux de ces parcs.

L'examen bactériologique des écouvillonnages effectués dans les cages en plastique utilisées pour transporter les poulets à l'abattoir, révéla que 86.6% d'entre elles, i.e. 97/112, recelaient déjà 15 sérotypes de salmonelles, avant qu'on y dépose les poulets. La laveuse dont on disposait à l'abattoir pour nettoyer les cages, n'en enleva pas les salmonelles; en effet, 73.5% ou 97 des 132 cages éprouvées à cette fin, recelaient des salmonelles après le lavage. On en isola 11 sérotypes, entre autres S. johannesburg et S.

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alachua, **qui provenaient vraisemblablement des poulets du troupeau en cause.**

Douze ou 38.7% des 31 poulets éprouvés à cette fin, à l'arrivée du troupeau à l'abattoir, s'avérèrent porteurs de S. johannesburg **et/ou de** S. alachua, **dans leurs intestins; on isola par ailleurs ces deux salmonelles, ainsi que quatre autres sérotypes, du plumage de 29 ou de 93.5% de ces 31 poulets.**

Onze ou 44% des 25 carcasses du troupeau éprouvées à cette fin recelaient des salmonelles. On isola de cinq d'entre elles S. johannesburg **et** S. alachua, **au préalable isolées du troupeau. On isola de six autres carcasses** S. haardt **et** S. typhimurium, **d'abord isolées des cages en plastique utilisées pour le transport des poulets à l'abattoir.**

INTRODUCTION

In order to reduce *Salmonella* contamination of poultry and poultry products, the sources of such contamination must first be identified, so that appropriate measures for control may be developed and implemented. Litter, feed and feed ingredients, newly hatched chicks and the processing plant environment have all been identified as sources of salmonellae contaminating processed poultry carcasses (2,3). In a recent report, we presented evidence that inadequately cleaned poultry crates may be another important source of contamination (6). In that study, 15% of the plastic crates used to transport an uninfected broiler flock to a commercial plant were found to be contaminated with salmonellae, and the same serovars were recovered from 2/23 birds sampled as they entered the plant and from 3/18 processed carcasses.

The broiler flock described in that study was raised in 32 pens at the Central Poultry Test Station (CPTS) in Ottawa as one of a series of broiler performance tests. This report describes a similar study of the broiler flock raised in the same building for the next performance test. During this test, however, salmonellae were isolated from seven of the pens during the growing period. Selected infected and uninfected pens were therefore studied in detail when the flock was sent for processing in an attempt to assess the importance of flock infection as a source of salmonellae entering the processing plant and contaminating processed carcasses.

The results indicated that flock infection, cross-contamination during transport, and inadequately cleaned crates were all sources of *Salmonella* contamination of processed carcasses from this flock.

MATERIALS AND METHODS

SAMPLING PROCEDURES

The broiler performance tests of which these studies form a part and the sampling procedures used have been described in detail (6). Briefly, hatching eggs were purchased from eight commercial breeder flocks located in different parts of Canada and nest litter samples were submitted for culture at the same time. All eggs were set and hatched in the same incubator at CPTS. Eggs which were infertile or contained dead embryos when candled after 18 days' incubation, eggs which failed to hatch after 21 days' incubation and fluff collected from the hatcher were submitted for culture. Samples of complete feeds and feed ingredients were collected at the feed mill and at the CPTS barn.

The CPTS barn contains 34 pens (305 cm x 397 cm) with concrete floors covered with new pinewood shavings litter to a depth of six cm. Seventeen pens are on each side of a central corridor (even-numbered pens on one side, and odd-numbered pens on the other). Thirty-two pens were used for the test. Four pens were allocated by random numbers to each of the eight broiler strains under test, and 130 chicks placed in each pen (0.093 m^2 per chick). Starter ration was fed to 24 days, grower ration to 37 days and finisher to 49 days of age. The manual feeding system used galvanized metal feeders.

a) *Growing Period.* Floor litter samples were collected from each pen before the chicks were placed (day 0) and after ten, 28 and 42 days. All chicks which died or were culled were submitted for necropsy and their intestines collected for culture.

b) *Pretransport Chickens.* Pens 6, 8, 11 and 19 were selected for detailed study during processing. On day 47, ten birds from each of these four pens were killed and placed in individual plastic bags. The exterior of each bird was sampled by the

rinse method (1) to recover salmonellae carried on the feathers and feet, and the lower intestine, including ceca, collected for culture.

c) *Crates and Posttransport Chickens.* On day 49 the flock was loaded into plastic transport crates. Each crate held 12 birds. The crates were loaded on the truck by 5 p.m., driven approximately 300 km to the plant and left on the truck until processing began at 7:30 a.m. the next day. The plant processed about 1500 birds an hour, using an automatic eviscerator. Processing was completely by 11:30 a.m. The crate washer used cold potable water under pressure, containing 2.5% disinfectant ("Creolin"). Each crate spent about 15 seconds in the crate washer. Crates were sampled by swabbing them: 1) before birds were loaded at the barn, 2) after they were unloaded at the plant and 3) after they had passed through the crate washer. At least 100 crates were sampled on each occasion. They contained visible deposits of manure, feathers and debris each time.

The 32 crates used for pens 6, 8, 11 and 19 were numbered. They were loaded last at the barn and unloaded first at the plant the next day. No attempt was made to separate them from each other or from the other crates on the truck. One bird in each numbered crate was wingbanded and one was marked with a felt pen. When these crates were unloaded at the plant, 31 of the 32 marked birds were recovered, killed and placed in invidivual plastic bags. Their exteriors were sampled by the rinse method (1) and their lower intestines, including ceca, collected for culture.

d) *Processed Carcasses.* The wingbanded birds in the numbered crates were processed and attempts made to collect these carcasses as they emerged from the chill tank. Twenty wingbanded carcasses were recovered. Five unmarked carcasses were also collected at the end of the day's processing. These carcasses were placed in individual plastic bags and cultured by the rinse method (1).

e) *Plant Environment.* Samples of the plant environment were collected as in the previous study (6). They included five carcasses processed the previous day, swabs from the chill tank before processing began and after processing was completed, and swabs collected from the defeatherer before processing began, at the midmorning break (10:00 a.m.) and after processing was completed.

CULTURE METHODS

These have been described (5, 6). Briefly, samples were cultured in tetrathionate-brilliant green broth (TBG). Litter, eggs, fluff and intestines were cultured directly in TBG, as well as after preenrichment in 0.1% peptone water (PW) for 18-24 hours at 37°C. Swabs and rinse fluids were all preenriched before culture. Tetrathionate-brilliant green broth cultures were incubated at 42°C for 24 hours, then plated onto brilliant green-sulfa agar (BGS). Brilliant green-sulfa agar plates were incubated 24-48 hours at 37°C. Samples which failed to yield salmonellae on these plates were also cultured by secondary enrichment (4): the preenriched TBG culture was left on the bench for seven to ten days, then subcultured to fresh TBG. This secondary enrichment culture was incubated 24 hours at 42°C, then plated onto BGS.

Where possible, at least four colonies resembling salmonellae on BGS plates were subcultured to triple-sugar-iron agar and provisionally identified by slide agglutination with antisera to *Salmonella* "O" antigens. *Salmonella johannesburg* was identified by slide agglutination with antiserum to *Salmonella* "O" antigen 40 and *S. alachua* by slide agglutination with antiserum to *Salmonella* "O" antigen 35. Other isolates reacted with polyvalent antisera. At least one isolate from each positive specimen was submitted for complete identification at the National Enteric Reference Centre, Ottawa.

Samples of feeds and feed ingredients were cultured by the Laboratory Services Division, Plant Products Directorate, as described (6).

RESULTS

a) *Parent Flocks, Incubated Eggs and Fluff.* Salmonellae were recovered from nest litter samples collected from two of the eight parent flocks. *Salmonella muenster, S. heidelberg* and *S. typhimurium* were recovered from one flock and *S. heidelberg* and *Salmonella* sp. (rough, untypable) from another.

However, salmonellae were not recovered from eggs cultured after 18 or 21 days' incubation or from fluff collected from the incubator after hatching was complete, indicating that salmonellae from the parent flock were not transmitted to the newly hatched progeny.

b) *Feed and Feed Ingredients. Salmonella johannesburg* was isolated from the meat meal which was incorporated into the starter ration, but not from the complete ration. No salmonellae were isolated from the grower or finisher rations or from their ingredients.

c) *Growing Period.* Twenty-five of the 32 pens in the barn failed to yield salmonellae from any of the four litter samples collected during the growing period. Table I shows the recovery of salmonellae from the seven positive pens. All pens were free of salmonellae at day 0, before the chicks were put out. After ten days, *S. johannesburg* was recovered from the litter of pens 11, 17, 19 and 20 and *S. alachua* was also recovered from the litter of pens 17 and 19. The same four pens, as well as two others (23 and 25) yielded *S. johannesburg* after 28 days and three of them (11, 19 and 20), as well as pen 18, yielded the same serovar after 42 days.

Mortality throughout the 49-day growing period was 3.4%. The most commonly diagnosed cause of death was "acute death syndrome". A total of 140 dead and culled chicks were necropsied and the intestines of each were cultured. Salmonellae were isolated from the intestines of 14 of these chickens, all of which originated from pens 19 and 20. Both of these pens also yielded salmonellae from the litter (Table I). Table II shows the isolation of salmonellae from these chicks. *Salmonella johan-*

TABLE I. Isolation of Salmonellae from Litter Collected from 32 Pens of Broiler Chickens at 0, 10, 28 and 42 Days of Age

Pen Numbers of Positive Pens[a]	Serovar(s)[b] Isolated on Day			
	0	10	28	42
11	—	jo	jo	jo
17	—	al, jo	jo	—
18	—	—	—	jo
19	—	al, jo	jo	jo
20	—	jo	jo	jo
23	—	—	jo	—
25	—	—	jo	—
No. positive pens / No. tested	0/32	4/32	6/32	4/32

[a] 25 of the pens did not yield salmonellae at any sampling time
[b] — = no salmonellae isolated, al = *S. alachua*, jo = *S. johannesburg*

TABLE II. Isolation of Salmonellae from the Intestines of Culled and Dead Chickens of Pens 19 and 20

Pen 19			Pen 20		
Bird No.	Day of Death	Serovar(s)[a]	Bird No.	Day of Death	Serovar[a]
N.B.[b]	2	—	N.B.	2	—
311	"	—	006	8	jo
1208	10	al, jo	349	"	jo
004	14	al, jo	1224	20	jo
1212	"	al, jo	331	22	—
1213	"	jo	1232	"	jo
1215	"	jo	337	"	—
1228	21	jo	1257	35	—
1229	"	al	1262	36	—
317	24	jo	1269	39	—
1237	"	jo	333	"	—
1261	35	—			
1265	38	jo			

[a] — = not isolated, jo = *S. johannesburg*, al = *S. alachua*
[b] — N.B. = no band

nesburg was the only serovar identified from birds of pen 20, but both *S. johannesburg* and *S. alachua* were recovered from chicks of pen 19. *Salmonella johannesburg* was first recovered from a chick which died on day 8 and *S. alachua* from a chick which died on day 10.

On the basis of these results, pens 6, 8, 11 and 19 were selected for detailed study during transport and processing. Pen 19 was infected with both *S. johannesburg* and *S. alachua*. Both these serovars had been recovered from chickens and litter samples from that pen. Pen 11 had yielded *S. johannesburg* from the litter but not from any of the chicks cultured from that pen. Pens 6 and 8 were uninfected pens, included for comparison. Pen 8, which contained chickens from the same parent flock as pen 19, had not yielded salmonellae and neither had pen 6, which contained chickens from the same parent flock as pen 11.

d) *Pretransport Chickens.* Table III shows the results of culturing ten chickens from each of pens 6, 8, 11 and 19 on day 47. No salmonellae were recovered from chickens of pens 6 and 8. *Salmonella johannesburg* was recovered from the exteriors of 7/10 birds from pen 11 but not from their intestines. All ten birds tested from pen 19 carried *S. johannesburg, S. alachua* or both on their exteriors and 7/10 were also intestinal carriers.

e) *Crates and Posttransport Chickens.* Because so many of these samples yielded salmonellae, it was not possible to identify more than one or two isolates from each sample. Therefore, the number of serovars reported here is a minimum for each sample.

Table IV shows the isolation of salmonellae from the numbered crates used to transport the birds of pens 6, 8, 11 and 19 and from the marked birds recovered from these crates when they were unloaded at the plant. Before these crates were loaded at the barn 30/32 yielded salmonellae. Seven serovars were recovered but *S. alachua* and *S. johannesburg* were not among them. When the crates were unloaded the next morning 32/32 were contaminated. *Salmonella johannesburg* and *S. alachua* were the predominant serovars recovered, even from crates which had transported uninfected birds from pens 6 and 8. Washing did not remove salmonellae from these crates, as 31/32 sampled after they had been through the crate washer still yielded salmonellae. *Salmonella johannesburg* and *S. alachua* were still the predominant serovars, although five other serovars were also recovered. Only once was the same serovar identified on all three occasions (crate 8-2). The same serovars were identified from five crates after washing and before loading.

Twenty-nine of the 31 chickens recovered from these crates were external carriers of salmonellae. Four of them yielded serovars that had not been recovered from the flock during the growing period, but which presumably were acquired during transport. All eight of the birds originating from "uninfected" pen 6 carried *S. johannesburg, S. alachua* or both on their exteriors and four of eight from "uninfected" pen 8 carried *S. johannesburg*. One chicken from this pen (8-6) also yielded *S. johannesburg* from its intestines. Even though *S. alachua* had not been identified from pen 11 during the growing period, it was recovered from the exteriors of two birds (11-4 and 11-6) and also from

TABLE III. Isolation of Salmonellae from the Exteriors and Intestines of "Pretransport" Chickens from Pens 6, 8, 11 and 19 Sampled on Day 47

Pen Number	Number Positive Chickens / Number Tested	Chickens: Exteriors — Number Positive	Exteriors — Serovars[a]	Intestines — Number Positive	Intestines — Serovars[a]
6	0/10	0	—	0	—
8	0/10	0	—	0	—
11	7/10	7	jo (7)	0	—
19	10/10	10	jo (9) al (4)	7	jo (2) al (5)

[a] — = no salmonellae isolated, jo = *S. johannesburg*, al = *S. alachua*
Number of isolates in parentheses

TABLE IV. Serovars[a] of Salmonellae Isolated from Numbered Transport Crates and from the Chickens of Pens 6, 8, 11 and 19 Transported in Them

Crate No.	Serovars(s)[a] Isolated from				
	Crates			Chickens[b]	
	Before Loading	After Unloading	After Washing	Exterior	Intestine
Pen 6					
6–1	infantis	infantis, jo	jo	al	—
2	albany	jo	albany	al, jo	—
3	muenchen	al, jo	jo	typhim, al, jo	—
4	infantis	al	typhim	al, jo	—
5	muenchen	al	infantis	al, jo	—
6	infantis	jo	infantis	al	—
7	heidelberg	al	jo	al	—
8	—	al, jo	al	al	—
Pen 8					
8–1	infantis	muenchen	jo	meunchen	—
2	muenchen	muenchen	muenchen	—	—
3	muenchen	typhim, al	—	jo	—
4	muenchen	al, jo	typhim, al	—	—
5	muenchen	jo	jo	jo	—
6	muenchen	jo	al	jo	jo
7	muenchen	jo	jo	jo	—
8	infantis	jo	al	haardt	—
Pen 11					
11–1	schwarz	jo	jo	jo	—
2	schwarz	jo	jo	bredeney, jo	jo
3	infantis	al	jo	jo	—
4	schwarz	al	bredeney, al	al	al
5	schwarz	al, jo	al	jo	—
6	infantis	jo	al, jo	jo	al
7	neinstedten	jo	jo	jo	—
8	albany	al	al	nd	nd
Pen 19					
19–1	heidelberg	jo	jo	jo	al
2	heidelberg	jo	jo	jo	jo
3	infantis	al	al	al, oj	jo
4	infantis	al, jo	infantis	jo	al
5	typhim	al, jo	jo	jo	al
6	infantis	al	infantis, jo	al, jo	jo
7	heidelberg	jo	jo	jo	al
8	—	al	al	al	al
No. positive / No. tested	30/32	32/32	31/32	29/31	12/31

[a]al = *S. alachua*, jo = *S. johannesburg*, schwarz = *S. schwarzengrund*, typhim = *S. typhimurium*, — = no salmonellae isolated, nd = not done

[b]One chicken from each crate was collected when the crates were unloaded. The chicken from crate 11–8 was lost at this time

the intestines of one of them (11-4).

Table V shows the isolation of salmonellae from all the crates sampled. The numbered crates used for birds of pens 6, 8, 11 and 19 are shown separately. Before loading, salmonellae were recovered from 97/112 crates (86.6%). Fifteen serovars were identified, but *S. johannesburg* and *S. alachua* were not among them. After the crates were unloaded at the plant, 50/96 (52.1%) unmarked crates yielded salmonellae. This lower incidence of contamination was probably because most of these crates would have contained chickens from the 25 uninfected pens whose feces would have been collected at this time. We do not know which crates contained birds from pen 20, which were infected with *S. johannesburg* or which contained birds from pens 17, 18, 23 and 25, whose litter had yielded salmonellae during the growing period. Those crates which yielded *S. johannesburg* and *S. alachua* may have contained birds from those pens or may have been loaded near them.

TABLE V. Isolation of Salmonellae from Numbered and from Unmarked Crates Sampled at Three Different Times

Sampling Time	Numbered Crates		Unmarked Crates		Total
	No. pos. / No. tested	Serovars[a]	No. pos. / No. tested	Serovars[a]	No. pos. / No. tested
Before Loading	30/32 (93.8%)	albany (2)[b] heidel (4) infant (10) muench (8) neinst (1) schwarz (4) typhim ( )	67/80 (83.8%)	agona (1) albany (10) anatum (1) haardt (9) heidel (4) indiana (1) infant (17) muench (9) neinst (1) newport (1) OR (2) (2) saintp (5) typhim (5) typhim c (1)	97/112 (86.6%)
After Un-Loading	32/32 (100%)	al (16) jo (20) muench (2) typhim (1)	50/96 (52.1%)	agona (1) al (5) albany (3) haardt (4) indiana (2) infant (6) jo (26) muench (1) typhim (7)	82/128 (64.1%)
After Washing	31/32 (96.9%)	al (12) albany (1) breden (1) infant (4) jo (16) muench (1) typhim (2)	66/100 (66%)	al (4) albany (4) haardt (5) heidel (1) indiana (2) infant (4) jo (35) muench (12) saintp (3) schwarz (1) typhim (7)	97/132 (73.5%)

[a]al = *S. alachua*, breden = *S. bredeney*, heidel = *S. heidelberg*, infant = *S. infantis*, jo = *S. johannesburg*, muench = *S. muenchen*, neinst = *S. neinstedten*, saintp = *S. saintpaul*, schwarz = *S. schwarzengrund*, typhim = *S. typhimurium* ; typhim c = *S. typhimurium* var *copenhagen*, OR = *Salmonella* sp (rough, untypeable)

[b]Number of times isolated in parentheses

After the crates had been washed and were being reloaded on the truck ready to go and collect birds for the next day's processing, 97/132 (73.5%) yielded salmonellae. *Salmonella johannesburg* and *S. alachua,* which had been introduced by birds from infected pens, were recovered from 66 crates but nine other serovars were also recovered. Obviously, the crate washing procedures did not remove the salmonellae contaminating these crates.

f) *Plant Environment.* Table VI shows the isolation of salmonellae from samples collected at the plant. *Salmonella haardt* had been present in the plant the previous day, since it was isolated from all five of the carcasses collected from the previous day's processing. However, salmonellae were not recovered from the defeatherer or chill tank before processing began, suggesting that the plant cleaning procedures effectively prevented the carry-over of contamination from one day to the next. *Salmonella johannesburg,* introduced by our flock, was recoverey from the defeatherer at the 10:00 a.m. break, two and one-half hours after processing began, and it was again recovered, along with *S. haardt,* after processing was completed. *Salmonella haardt* could have remained in the plant from the previous day or it could have

TABLE VI. Isolation of Salmonellae from the Processing Plant Environment

Samples	Number Positive / Number Tested	Serovar(s)
Carcasses processed the previous day	5/5	*S. haardt*
Chill tank swab		
— before processing	0/1	
— after processing	1/1	*S. johannesburg* *S. typhimurium*
Defeatherer swabs		
— before processing	0/3	
— at 10 : 00 a.m.	1/3	*S. johannesburg*
— after processing	3/3	*S. johannesburg* *S. haardt*

TABLE VII. Isolation of Salmonellae from Processed Carcasses

Group	Number Positive[a] / Number Tested	Serovar(s)[b]
Pen 6 "uninfected"	1/4	*S. typhimurium* (1)
Pen 8 "uninfected"	1/4	*S. typhimurium* (1)
Pen 11	3/6	*S. typhimurium* (2) *S. alachua* (1)
Pen 19	4/6	*S. alachua* (3) *S. johannesburg* (1)
"Last 5 of the day"	2/5	*S. haardt* (2)
Total	11/25 (44%)	

[a]Four carcasses were recovered that originated from each of pens 6 and 8, and six that originated from each of pens 11 and 19
[b]Number of isolates in parentheses

been reintroduced by chickens which were shipped in crates contaminated with this serovar. After processing was completed, *S. johannesburg* and *S. typhimurium* were recovered from the chill tank. *Salmonella typhimurium* was also recovered from crates.

g) *Processed Carcasses.* Table VII shows that 11/25 (44%) processed carcasses recovered from this flock yielded salmonellae. *Salmonella alachua* or *S. johannesburg* were recovered from four of six carcasses originating from pen 19, which was infected with both these serovars. Carcasses from pen 11 yielded *S. alachua* and *S. typhimurium*. Their first known exposure to both these serovars was during transport. One carcass from pen 6 and one from pen 8 yielded *S. typhimurium* which was first recovered from the crates. Two of the five carcasses collected at the end of processing yielded *S. haardt* which was also isolated from the crates and from carcasses processed the previous day.

DISCUSSION

We were fortunate in this study that the natural infection which we detected during the growing period was due to two relatively uncommon serovars, *S. johannesburg* and *S. alachua*, both of which were identified very quickly by slide agglutination using specific antisera. Neither of these serovars was isolated from transport crates before the flock was loaded or from samples of the plant before the flock was processed. Therefore we assumed that contamination with these two serovars originated from pens which we knew were infected during the growing period.

Because so many isolates were obtained, especially from samples collected before

and during transport and processing, it was impossible to identify more than one or two from each specimen. Even so, the large number of serovars which were identified leads us to suspect that many specimens must have contained several serovars and the number of isolates of each reported here is minimal.

Feed has been identified as a source of salmonellae for growing broiler flocks (2, 3). Since *S. johannesburg* was recoverred from the meat meal component of the starter ration, it was likely present in the complete ration as well, either because it was able to survive the manufacturing process in small numbers or because of recontamination of complete feed. The isolation of *S. alachua* from litter and chicks after ten days suggests that this serover may also have been introduced in the feed. If these salmonellae were present in the feed in very low numbers or were unevenly distributed, they may not have been detectable when the complete feed was cultured. This would also help to explain why infection was detected in only two of the 32 pens (19 and 20). Salmonellae were recovered from the litter of five other pens (11, 17, 23 and 25). Since pens 23 and 25 were adjacent and pens 17 and 19 were also adjacent and situated directly across the corridor from adjacent pens 18 and 20, limited pen-to-pen spread of infection may have occurred during the growing period. However, 25 of the 32 pens remained apparently free of salmonellae.

Salmonellae may apparently be introduced into pens of growing broilers without necessarily initiating a flock infection. Even though the litter of pens 11 and 17 yielded salmonellae when the chicks were ten days old, no infected chicks were detected in these pens. On day 47, 7/10 chickens sampled from pen 11 were external carriers of *S. johannesburg* but no intestinal carriers were detected. These results suggest that contamination of the feathers of growing broilers may be more common than intestinal carriage of salmonellae. Twenty-nine of the 31 "post-transport" chickens cultured were external carriers of salmonellae, but only 12 of them were intestinal carriers. It is possible that salmonellae entering a processing plant on the feathers of incoming birds may be a more important source of contamination than salmonellae which they carry in their intestines.

Salmonella johannesburg and/or *S. alachua* were recovered from all the "post-transport" chickens sampled from uninfected pens 6 and 8. These chickens may have had a low level of infection, undetected during the growing period, which was "activated" during transport, or they may have been contaminated during loading at the barn. However, the most likely explanation for the high incidence of contamination in these birds is that cross-contamination occurred between crates while they were on the truck. In a separate study, cross-contamination occurred readily between crates of broilers subjected to simulated shipping and it was suggested that this may occur commonly under commercial conditions (5).

Eleven of the 25 carcasses tested from this flock yielded salmonellae, but only five of these were contaminated with the two serovars which had been isolated from the flock during the growing period. The other six carcasses yielded serovars that had been recovered from the transport crates and from the plant. It would be interesting to know how long the two serovars introduced by our infected flock would survive in the plant and in the crates and how much contamination they would contribute to subsequent flocks processed at that plant.

The results of this study indicated that three main sources of salmonellae contributed to the contamination of processed carcasses from this flock. Flock infection with *S. johannesburg* and *S. alachua,* presumably introduced by contaminated feed, was the most likely source of these serovars on carcasses originating from pen 19. Cross-contamination during shipping resulted, as far as we could tell, in the first exposure of birds of pen 11 to *S. alachua* and this serover was subsequently isolated from a carcass originating from that pen. Contaminated crates were used to transport this flock to the processing plant and *S. haardt* and *S. typhimurium,* which were recovered from the crates, were subsequently recovered from the plant and from processed carcasses.

The improvement of crate washing procedures, to ensure that crates are adequately cleaned and disinfected at the processing plant to eliminate this source of salmonellae, would help reduce contamination of processed poultry. Further studies are needed to improve the design and construction of crates and crate

washing equipment and the use and types of disinfectants, in order to ensure that adequate disinfection of crates is achieved under commercial conditions.

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