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Salmonella in pig carcasses for human consumption in Hong Kong: a study on the mode of contamination

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SUMMARY

A very high proportion (75%) of the pigs slaughtered in Hong Kong were found to be infected with salmonellas. Seven serotypes including *Salmonella choleraesuis* were isolated but the majority (91%) were *S. anatum* and *S. derby*. These serotypes, especially *S. anatum* and *S. derby*, had been isolated frequently from clinical cases, symptomless carriers and in this study from abattoir workers, suggesting that the pig was a significant source of human salmonella infection.

The majority of pigs slaughtered are imported and the high level of apparent infection was thought to be due to cross-infection during transport of the pigs under stress. *S. anatum* and *S. derby* were also isolated from pigs on local farms but the incidence was threefold lower. Scalding the pigs at 60 °C for 5 min caused no great reduction in the degree of superficial contamination. The two predominant serotypes were isolated from the tank and from drain swabs, and also from the latter held under scalding tank conditions. Thus, in spite of the introduction of hygienic slaughter under modernized conditions employing an automatic conveyance system, 55% of the carcasses were superficially contaminated after dressing before despatch to customers. Control of infection before slaughtering would appear crucial and a more thorough rinsing or washing of the dressed carcasses desirable.

INTRODUCTION

The carcasses or products of infected domestic animals and birds are the commonest sources of food-poisoning salmonellas. However, their relative importance appears to vary from place to place. For example, in Britain, poultry, particularly hens, ducks and turkeys, were the most significant sources of salmonellas (Gillies, 1973) and in the Netherlands pork was the most important source of infection for man (Edel, Van Schothorst, Guinée & Kampelmacher, 1973). In an earlier investigation in Hong Kong, Lo, Huang & Chan (1967) showed by faecal examination that a high proportion (27%) of pigs slaughtered for human consumption were infected with salmonellas, suggesting this animal might be an important source of human salmonellosis. They speculated that the habit of eating pig offal by the local population contributed to the prevalence of human salmonellosis in the locality. After the completion of their investigation, a modern abattoir has been built with an automatic conveyance system for handling the animals from ante-mortem inspection through to the time the

carcasses leave the abattoir. Taking account of this background information, that pork is the most important animal meat in Hong Kong and that human salmonellosis is prevalent here, we further investigated as systematically as was feasible the following problems: (1) the importance of pigs as the source of human salmonellosis, (2) the manner in which contamination of pork occurs and (3) the significance of a modernized abattoir in relation to the contamination of the meat. An efficient semi-solid enrichment-indicator medium procedure described by Chau & Huang (1976) has been used throughout the study for salmonella detection.

MATERIALS AND METHODS

The pigs and the slaughtering process

Specimens were collected from the newly constructed Kennedy Town slaughter house in Hong Kong. Approximately 90% of the pigs slaughtered in this abattoir were imported from unknown localities in China, the remainder coming chiefly from the rural New Territories, Hong Kong. The duration of the journey for those from China might be up to a week or more. The pigs were slaughtered within hours of their arrival at the abattoir or at most 1 day.

After ante-mortem inspection the pigs were stunned electrically and immediately suspended by one leg from an elevated conveyance system. The jugular vein was pierced and the animal carried along the system for a sufficient period of time to allow exsanguination, after which the body surface was rinsed by overhead sprinklers for several seconds. The pig was subsequently removed from the system into a scalding tank held at 60 °C, dehaired during its passage through the tank lasting 5 min and then attached by the hind legs to another automatic conveyance system in a hanging position prior to dressing. A longitudinal ventral cut was made and the whole viscera removed onto a tray for immediate inspection and subsequent direct despatch to the floor below. The carcass was also inspected and then submitted to further rinsing by overhead sprinklers before delivery to customers in the market.

Materials examined and the cultural procedure

Abattoir pigs

A total of 1026 specimens distributed as indicated in the Results section were taken during April to July 1976 from pigs processed as described above, and examined for the presence of salmonellas. Specimens were taken at random and it was not feasible to relate them back to a given animal.

Blood clots. Blood from the gushing jugular vein was used to minimize superficial contamination. Samples were collected into a sterile bottle for each pig in approximately 25 ml volumes. After removal of the serum, the clot was broken with a Pasteur pipette and about 20 ml of a Gram-negative (G.N.) broth (Hajna, 1955) was added.

Rectal swabs. These were collected from the inverted individual animal at a station in the conveyance system before scalding.

Body. The body surface of the pig was swabbed subsequent to exsanguination

and first rinsing but before scalding. This was done in order to gauge the degree of superficial contamination as it was not possible to take ante-mortem swabs.

Carcasses. Swabs were taken from the surface immediately after scalding, and from the external and internal aspects of the carcasses after dressing and final rinsing.

All swabs taken above were immediately inoculated into tubes containing 10 ml of G.N. broth.

Farm pigs

Rectal swabs were taken from individual pigs held in pens on farms in the New Territories, Hong Kong, and inoculated into G.N. broth tubes.

Drainage swabs

Specimens were collected from the abattoir drains by Moore's gauze swab method (Moore, 1948). Two swabs were taken from each of the ten drain sites. One set of ten swabs was each suspended in 100 ml sterile water at room temperature, the other in water at 60 °C and held for 5 min. Ten ml samples of these water specimens were withdrawn and mixed with an equal volume of double strength G.N. broth.

Scalding tank

Water specimens were collected in sterile bottles suspended in the tank by a long wire. A 10 ml sample of each specimen was added to a bottle containing double-strength G.N. broth.

Abattoir workers

One faecal specimen was collected from each abattoir worker. About 0·1 g of the faecal material of each specimen was inoculated into a tube containing 10 ml of G.N. broth.

Cultural procedure

All specimens collected into G.N. broth were incubated at 37 °C for 6–8 h before subculture into U-shaped tubes containing a semi-solid enrichment-indicator medium of Chau & Huang (1976). This enrichment medium contained magnesium chloride, brilliant green and novobiocin as the main selective substances while the indicator medium layered on the former was a H_2S production medium selective for salmonellas. After incubation at 41 °C for 42–48 h, bacterial growth characteristic of salmonellas at the uninoculated end of the semi-solid medium was subcultured on MacConkey agar, from which colonies were picked for serotype identification.

RESULTS

Salmonella isolations in the abattoir

Rectal swabs. Of 462 rectal swabs from imported pigs which were examined, 344 (75%) were found to be positive for salmonellas (Table 1). The positive rate,

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Table 1. *Frequency of salmonella isolations from rectal swabs of pigs*

Batch no.	No. of swabs taken	Positive swabs	Number of salmonella isolations						
			S. anatum	*S. derby*	*S. typhimurium*	*S. london*	*S. choleraesuis*	*S. newport*	*S. meleagridis*
1	24	7 (29)*	3	1	—	—	3	—	—
2	54	29 (54)	16	6	2	1	2	1	1
3	49	41 (84)	24	14	—	3	—	—	—
4	37	22 (60)	17	2	—	2	—	1	—
5	40	35 (88)	35	—	—	—	—	—	—
6	50	39 (78)	31	5	3	—	—	—	—
7	50	46 (92)	38	3	3	—	—	2	—
8	50	31 (62)	20	9	2	—	—	—	—
9	49	48 (98)	40	8	—	—	—	—	—
10	59	46 (78)	31	10	2	1	—	1	1
Total	462	344 (75)	255 (55)	58 (13)	12 (3)	7 (2)	5 (1)	5 (1)	2 (0·4)

* Figures in parentheses indicate percentages.

Table 3. *Frequency of salmonella isolations from swabs taken from the body surface of pig carcasses*

Swabs examined	No. of swabs examined	Number of salmonella isolations				
		Total	*S. anatum*	*S. derby*	*S. newport*	*S. typhimurium*
External surface						
Before scalding	17	16 (94)*	14	1	—	1
Right after scalding	22	14 (64)	11	3	—	—
After dressing	105	58 (55)	42	13	2	1
Internal surface						
After dressing	58	1 (2)	1	—	—	—

* Figures in parentheses indicate percentages of the number of salmonella isolations to the total number of specimens examined at each stage.

Table 2. *Frequency of salmonella isolations from blood clots of pigs*

Batch no.	No. of specimens taken	Total	Number of salmonella isolations		
			S. derby	*S. anatum*	*S. typhimurium*
1	63	3 (5)*	2	1	—
2	71	4 (6)	1	2	1
3	33	2 (6)	1	1	—
4	67	3 (5)	1	2	—
5	31	7 (23)	4	2	1
6	36	2 (6)	1	—	1
7	32	0 (0)	—	—	—
8	39	2 (5)	1	1	—
Total	372	23 (6)	11 (3)	9 (2)	3 (1)

* Figures in parentheses indicate percentages.

however, varied greatly from one batch of specimens to the other ranging from 29% to 98%. The salmonellas isolated belonged to seven serotypes – *S. anatum*, *S. derby*, *S. typhimurium*, *S. london*, *S. choleraesuis*, *S. newport* and *S. meleagridis*, in that order of frequency: the first two constituted 91% (313 out of 344) of the total isolations.

Blood clots. Salmonellas were isolated from 23 (6%) of the 372 clot specimens examined (Table 2). Here also there was batch-to-batch variation, the positive rate ranging from zero to 23%. Only three salmonella serotypes – *S. derby*, *S. anatum* and *S. typhimurium* – were identified; their frequencies of isolation were 3%, 2% and 1%, in contrast to those from rectal swabs which were 13%, 55% and 3% respectively (Tables 1, 2).

Swabs taken from pig carcasses. Swabs were taken from the outer (skin) surface of pigs at different stages of processing. Salmonella organisms were isolated from 16 (94%) of the 17 swabs taken before scalding, 14 (64%) of the 22 swabs taken immediately after scalding and 58 (55%) of the 105 swabs taken after removal of pigs' internal organs for dressing (Table 3). Examination of 58 swabs taken from the internal aspect of the pig carcasses yielded only 1 salmonella isolation (2%).

Water samples from the scalding tank. Twenty water samples, each of 10 ml, were taken from the scalding tank; *S. anatum* was isolated from 2 and *S. derby* from 1.

Drain swabs. S. anatum was isolated from 9 and *S. derby* from 1 of the first set of 10 drain swabs suspended in water at room temperature. On the other hand, *S. anatum* was isolated from all 10 drain swabs of the second set suspended in water at 60 °C after a holding period of 5 min.

Faecal specimens from abattoir workers. One faecal specimen was collected from each of the 78 abattoir workers. *S. anatum* and *S. derby* were each isolated from 3 workers, giving a carrier rate of 8%.

Salmonella isolations from pigs on local farms

Of the 67 rectal swabs examined, 12 were found positive for *S. anatum* and 2 for *S. derby*, giving a positive rate of 21%.

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DISCUSSION

The isolation of salmonellas from pigs by the examination of rectal swabs and the external aspects of pig carcasses with incidence up to 75% and 55% respectively strongly suggests that pork, the most popular type of animal meat locally, is an important source of human salmonellosis in Hong Kong. All the seven salmonella serotypes isolated from pigs were also the commonest from human clinical cases (unpublished data), but in a different order of frequency as follows: *S. derby*, *S. typhimurium*, *S. anatum*, *S. london*, *S. newport*, *S. meleagridis* and *S. choleraesuis*. *S. anatum* and *S. derby*, which comprised 74% (255/344) and 17% (58/344) of the salmonella isolations from pig faeces, also accounted for 40% and 22% respectively of the salmonella isolations from human carriers (Chau & Huang, 1971) and were the only two serotypes isolated from apparently healthy abattoir workers in this investigation. Thus these two serotypes, in particular *S. anatum*, appear to be of lower pathogenicity or invasiveness than such salmonellas as *S. typhimurium*, and at the same time can well adapt to different kinds of hosts, mostly without causing symptoms. Nominal support for this contention comes from the finding that *S. anatum*, *S. derby* and *S. typhimurium* were isolated from 55%, 13% and 3% respectively, of pigs by faecal examination but only from 2%, 3% and 1% respectively of the blood clots.

Undoubtedly the intestinal contents of infected pigs are a rich source of salmonellas. The mesenteric lymph-nodes of pigs may also be significantly infected with salmonellas (Field, 1959; Lo *et al.* 1967). Their infection also indicates infection of the pig offal. Nevertheless, no matter how highly infected the offal may be, it does not appear to be a significant source of superficial contamination of the carcasses for two reasons; first, the whole viscera were regularly observed to be clearly removed from the body and, after immediate inspection, conveyed directly to the floor below, and secondly, there was a low incidence ($< 2\%$) of salmonellas detected on the internal aspect of the carcasses. Although systemic infection may play a role in the contamination of the meat, the fact that only 6% of the blood clots were contaminated suggested that the bulk of the contamination might be derived from the surface of the carcasses.

The scalding process caused a nominal decrease in superficial contamination of the pigs from around 94% to 64%, which in practical terms meant that the carcasses remained heavily contaminated before dressing. Indeed, contamination of water in the scalding tank with salmonellas suggested that heating conditions of 60 °C for 5 min were insufficient to deal with the vast input of salmonellas into the system. While the dynamics of salmonella contamination of the tank are complex, the simple demonstration that immersion of the drain swabs in water at 60 °C for 5 min failed to kill most of the salmonellas indicates that the scalding process was essentially ineffective in reducing contamination. A rinsing by overhead sprinklers after dressing only slightly reduced the contamination of the carcasses from 64% after dressing to 55% before release to the market. A more vigorous rinsing or washing of the carcasses should be introduced for decontamination.

When compared with the previous study carried out in an old-fashioned slaughter house (Lo *et al.* 1967) it was interesting to find that hygienic slaughter carried out in a modernized abattoir did not necessarily lead to a reduction of salmonella contamination. Further improvement in the hygienic slaughtering process is required and control of infection in the pigs themselves would seem more important.

The majority of pigs used for meat in Hong Kong are imported and about 8000 pigs were slaughtered per day. While the predominant serotypes isolated from both the imported and the local pigs were *S. anatum* and *S. derby*, 75% of the imported animals were infected in contrast to 21% raised on local farms. This high infection rate in the imported pigs is most probably due to cross-infection arising as a result of their transport, usually under crowded conditions and stress, often for as long as a week, to Hong Kong. Such conditions would almost certainly increase the chance of cross-infection. Infected pigs may pollute the lairage, leading to heavy contamination of the body surface of pigs and, more importantly, the liquid feeds such as swill and mash, thereby facilitating spread.

William & Spencer (1973) maintained that attention to the methods of transport, reduction of stress in the animals and improved systems of feeding were important in the reduction of salmonella in meat. In addition to this, we suggest that vigorous rinsing or washing of the dressed carcass by special devices would also seem well worth while.

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