

SPECIAL ARTICLE

Poultry meat as a source of human salmonellosis in England and Wales

Epidemiological overview

In England and Wales human salmonellosis is a major public health problem and, although mortality is low, the disease has important social and economic consequences. All surveillance indicators suggest that an epidemic of unprecedented proportions is occurring. Between 1981 and 1986 the number of strains received for serotyping by the Public Health Laboratory Service (PHLS) Division of Enteric Pathogens has increased by 66% (Table 1). This is predominantly due to strains of *Salmonella typhimurium* and *S. enteritidis*. Smaller but significant increases have occurred in the numbers of *S. virchow* and *S. stanley*. With the exception of the latter serotype, which seems to come from a bovine reservoir, the indications are that poultry is the main source of the increase in infections.

Salmonellosis is a zoonotic disease with a complex epidemiological cycle. The infection is most commonly food-borne and in England and Wales poultry remains a major vehicle as shown in Table 2 which is based on the food poisoning reports of the PHLS. Travellers returning from abroad account for about 20% of reports.

Salmonella typhimurium remains the most common serotype in 1986 as it did in 1981 (Table 1). An analysis of the data (Table 3) shows, however, that the phage types (PTs) currently found in poultry account for a greater proportion of human infections than was seen in 1981 (Table 4). The important changes appear to be due to:

(a) Several PTs which between 1981 and 1986 have spread from bovines to chickens - PTs 43a, 9, 204c.

(b) An increase in the incidence in poultry of several PTs which were found in bovines and chickens in 1981. These include PTs 43, 110, 141 and 193 with the most important being PT 141.

(c) Three PTs, 66, 135, and 208, with insufficient data to pin-point the main reservoirs but they are unlikely to include poultry.

Despite the importance of poultry as a salmonella reservoir, the significance of bovine salmonellosis must not be forgotten. Reports under the Zoonoses Order, 1975 show that from 1981 to 1985 incidents in bovines have increased by 12%.

Salmonella enteritidis now accounts for 28% of human infections compared with 11% in 1981 (Table 1). Three phage types, 4, 6 and 8, dominate the epidemiological pattern and cause about 90% of infections. With the exception of PT 6, which is almost exclusively seen in travellers, the evidence implicates poultry as the main source. PT 8 is indigenous to poultry in England and Wales and PT 4 is being isolated from poultry meat and eggs with increasing frequency (unpublished data). A proportion of PT 4 infections is also acquired abroad, notably in Spain and Portugal.

Table 1. *Salmonellas isolated from humans in England and Wales*

Year	<i>S. typhimurium</i>	<i>S. enteritidis</i>	Other serotypes	Total
1981	3992 (39)*	1087 (11)	5172 (50)	10251
1986	7094 (42)	4771 (28)	5111 (30)	16976

* Percentages in parentheses.

Table 2. *Salmonella food poisoning: suspected vehicles of infection in family and general outbreaks*

Years	Total number of vehicles	Number associated with poultry
1959-62	70	9 (12.9)
1969-72	127	66 (52.0)
1981-83	347	179 (51.3)
1984, 1985*	177	57 (32.2)

* 1985 PHLS Communicable Disease Surveillance Centre - unpublished.

Table 3. *Salmonella typhimurium isolated from human cases (England and Wales)*

Order	1981		1986	
	Phage type	%	Phage type	%
1	12a	11.4	49	12.5
2	10	10.9	12	7.8
3	12	8.9	141	7.7
4	204a	7.7	170	5.8
5	204	6.8	193	5.5
6	104	6.7	9	5.4
7	170	6.0	49a	5.4
8	49	3.7	204	5.4
9	193	2.6	110	5.3
10	110	1.6	204c	4.2
	Other types	33.7	Other types	35.0
Totals	3992	100	7094	100

Table 4. *Salmonella typhimurium phage types from poultry*

1981		1986	
Phage type	Number	Phage type	Number
145	15	49	65
204	11	193	19
204a	9	9	12
110	5	204a	8
U285	5	110	6
		141	5
Others	48	Others	33
All PTs	93		148

During the early 1970s poultry-associated outbreaks with *S. virchow* were commonly seen but this was followed by several years of declining incidence. However, human infections with *S. virchow* have increased by 30% in the period 1981–6 and poultry seems to be the source.

This demonstration of the role of poultry meat as a source of human salmonellosis necessitates a review of the current practices in poultry meat production and an evaluation of existing and potential control measures.

Control in husbandry practices

Commercial poultry flocks are prone to infection with food-poisoning salmonellas, especially during the early weeks of life. Under modern conditions of intensive production these pathogens are readily transmitted among the birds of a given flock or from flock to flock. The organisms are ingested by birds, become localized in the caeca without inducing clinical disease (Brownell *et al.* 1970; Fanelli *et al.* 1971) and are shed with the faeces into the rearing environment. The presence of salmonellas in the gut, on the skin and among the feathers will cause contamination of carcasses during subsequent slaughter and processing.

The main sources of flock infection are (a) contaminated feed (b) vertical transmission of the organisms from the breeder flocks to meat birds via the hatchery, and (c) the rearing environment, involving vectors such as rodents, insects, wild birds, domestic pets and man (Smith, 1971). Salmonellas are also recycled between animals, man and the general environment.

Contamination of feedstuffs is usually the most important source of infection in poultry (Williams, 1981*a*), and a relationship is apparent between contaminated feed, the incidence of particular serotypes in poultry and the appearance of these organisms in outbreaks of human salmonellosis. Salmonellas in feed are largely associated with the protein component, especially that of animal origin (meat-and-bone meal, fish meal, etc.) although vegetable protein and other ingredients can also be contaminated. Heat-processing in feed production should be sufficient to destroy salmonellas or reduce their incidence below the level required to infect poultry, but may fail to do so, especially when conditions of treatment are inadequate or opportunities exist for recontamination of the finished product.

There are a number of legislative measures aimed at reducing salmonella infection in poultry and other animals, and surveillance of the situation in a range of food animals is provided by the 1975 Zoonoses Order. This stipulates compulsory notification of all salmonella isolations.

Two specific measures to control contamination of animal feed were introduced in 1982. These were the Diseases of Animals (Protein Processing) Order 1981 and Importation of Processed Animal Protein Order 1981. As a consequence, animal protein intended for incorporation into feedstuffs is required to be free from salmonellas and plants are subject to periodic spot checks, the frequency of which will depend upon their performance. The importation order requires only compliance with the conditions of an import licence that makes imported material available for sampling on arrival at the dockside.

Sampling of domestic protein products in England and Wales from 1982–5 led to salmonella isolations at 55 of the 102 registered premises examined (excluding those ensiling poultry manure) and contamination rates for different products

varied from 0·7% for white fish meal to 25·7% for feather meal (Matthews, 1986). In total, 29 known serotypes of salmonella were isolated from 318 positive samples and the serotypes present corresponded closely with those found in food animals. The sampling of imported animal protein over the same period gave a similar picture, with 16·4% of 2020 samples being salmonella-positive by comparison with 9·5% for domestic production.

Present legislation does not prevent the use of salmonella-contaminated materials and has no requirement for a system of production in which 'clean' and 'dirty' materials are completely separated to prevent recontamination of the finished product. Standards of management and hygiene at some plants are also regarded as poor (Matthews, 1986). Existing measures thus do little to prevent potentially contaminated feed from entering the food chain.

Although heat-processing is the most widely used means of reducing salmonella contamination of animal feeds, other types of treatment are possible (Williams, 1981*b*). One approach is to incorporate an antimicrobial compound such as formic or propionic acid or a mixture of the two. This destroys salmonellas already present in feed and protects it against subsequent contamination; furthermore, its use does not require any withdrawal period. Commercial utilization has so far been limited, probably because of cost, but Humphrey & Lanning (1988) found that treatment of feed given to egg-laying hens reduced significantly the vertical transmission of salmonellas.

Prior to 1969, antibiotics such as penicillin and the tetracyclines were incorporated in animal feeds as growth promoters. This led to the emergence of resistant bacterial strains and the possibility of transferring such resistance to human enteric pathogens. In 1971, legislation was introduced prohibiting the use of antibiotics important in human therapy. Subsequently, several new antibiotics were developed by the pharmaceutical industry, specifically for use as animal growth promoters and not intended for use in human medicine.

Some antimicrobials may prolong the salmonella carrier-state in poultry by disturbing the ecological balance of the gut and inhibiting key organisms responsible for limiting intestinal populations of salmonellas. Various antimicrobial feed additives, especially those permitted for animal growth promotion, were examined by Smith & Tucker (1975, 1978, 1980). Virginiamycin or bacitracin incorporated in feed at 10 or 100 mg/kg had little effect on the excretion of *S. typhimurium* by chickens, but in some cases 100 mg/kg of nitrovin, flavomycin, lincomycin or tylosin increased the numbers of salmonellas being shed and often prolonged the period of excretion to the point of slaughter. Similar results were obtained with 10 mg/kg avoparcin. For various reasons, the future of all antimicrobial feed additives is currently being debated within the European Economic Community (EEC).

In some of the larger, integrated poultry companies, vertical transmission of salmonellas from infected breeding stock presents a particular problem, and the cycle of infection must be broken at the breeder stage if salmonellas are to be controlled effectively in meat flocks. With chickens and turkeys, direct ovarian transmission is rare, and infection of chicks usually results from faecal contamination of the eggs by birds which are excreting salmonellas. As the egg cools after laying, salmonellas on the outside can be drawn through the shell,

finally being ingested by the developing chick, where the organisms can multiply in the gut, and with little competition from other micro-organisms at this stage, rapidly reach high numbers. Such infections are easily spread to other chicks in the hatcher (Cox *et al.* 1973).

Frequent egg collection, prompt fumigation of eggs with formaldehyde or dipping in an antibiotic solution help to avoid early chicken infection, but elimination of salmonellas from breeder birds is more difficult. Attempts to do so usually involve treatment of the birds over a week or more with one or two antibiotics such as tetracycline and neomycin at therapeutic levels. Even with a light salmonella infection, however, Smith (1978) showed that whilst neomycin treatment reduced the incidence of chickens shedding *S. typhimurium*, the incidence of caecal infection reverted to its original state when treatment ceased. Medication of birds to reduce or eliminate salmonella infection is likely to have a marked, disruptive effect on the normal intestinal microflora and, once the treatment is discontinued, the birds are highly prone to reinfection. Evidence suggests that the problem could be overcome by quickly re-establishing a mature gut microflora through oral administration of cultured caecal content from an appropriate donor bird, as described by Seuna & Nurmi (1979) and Seuna *et al.* (1980). Recent use of this combined treatment for breeder birds in the UK is showing promising results (Mead & Impey, unpublished), and there is increasing interest in the 'competitive exclusion' principle as a means of reducing flock infection in various countries.

Salmonella and poultry processing

Poultry slaughter is a multi-stage operation (Fig. 1), and modern plants can process up to 200 birds per minute. The major emphasis has been on speedy and cost-effective production with prevention of cross-contamination being of less importance. Thus, the incidence of carcass contamination with salmonellas often exceeds that of infection in the live bird (eg. Notermans *et al.* 1975; McBride *et al.* 1980).

Such cross-contamination can occur during transport to the factory and at many points on the slaughter line. Certain stages, however, are of particular importance.

After the birds are exsanguinated they are 'scalded' in hot water for up to 4 min to facilitate plucking. Two scalding regimens, 'soft scalding' at 50–52 °C or 'hard scalding' at 58 °C or above, are used. The former is primarily for fresh birds, which are increasing in popularity over the frozen variety, and represents the greatest potential hazard.

Scalding can result in carcass contamination of surfaces and deep tissues with pathogenic microorganisms (Lillard, 1973; Notermans *et al.* 1975; Mulder, Dorresteyn & Van der Broek, 1978). It is also inefficient in killing or removing organisms attached to chicken skin (Notermans & Kampelmacher, 1975), and those that survive scalding are more difficult to remove during the later stages of processing.

Crabb & Walker (1971), suggested that the use of chemicals could reduce cross-contamination during scalding. This approach, however, has not proved successful

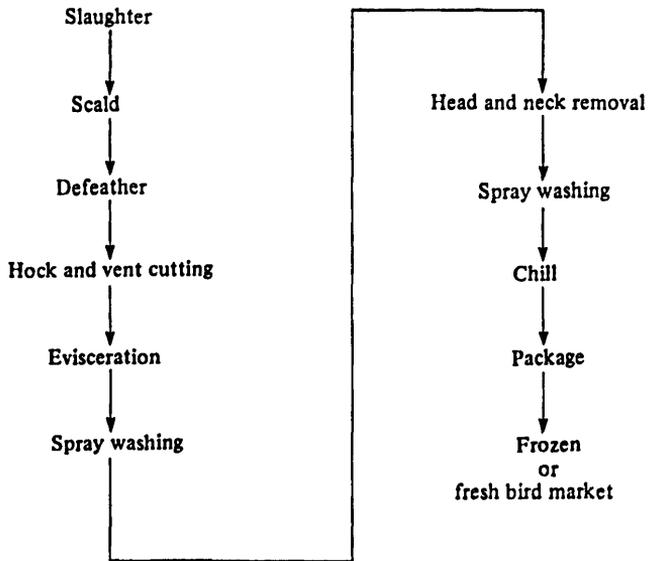


Fig. 1. Outline of stages in a typical poultry processing plant (McMeekin & Thomas, 1979).

and, for example, the use of caustic soda (Humphrey, Lanning & Beresford, 1981) or acetic acid (Okrend, Johnson & Moran, 1986), had no effect on the contamination of carcasses with salmonellas (Humphrey & Lanning, 1987; Lillard *et al.* 1987).

The extent of cross-contamination during plucking is governed by the hygiene of the scalding process. Alternatives have been developed, including simultaneous scalding and plucking and steam scalding (Klose, Kaufman & Pool, 1971; Patrick, Colins & Goodwin, 1973; Veerkamp & Hofmans, 1973). These minimize cross-contamination with salmonellas, but can be more expensive than immersion scalding and are unlikely to be adopted by the trade at present.

Intestinal contents can be heavily infected with salmonellas (Smith, 1969, quoted in Crabb & Walker, 1971) and thus the process of removing the intestine often results in carcass contamination (Bryan *et al.* 1968).

This process is carried out automatically for chickens, and equipment is calibrated for birds of a particular size or weight. While every effort is made to standardize this, there are natural variations which can lead to damage to the viscera, and contamination of the carcass with gut contents. Equipment thus soiled can transfer organisms to subsequent carcasses.

In the EEC, carcasses must be washed after evisceration. Spray washing can bring about significant reductions in the numbers of salmonellas (Bryan *et al.* 1968; Morris & Well, 1970). Super-chlorination of washing water (40 p.p.m.) reduces bacterial contamination on equipment (Bailey *et al.* 1986) and carcasses (Sanders & Blackshear, 1971). If high chlorine levels are maintained, however, damage to equipment can result and multiple spraying (Notermans, Terbijhe & Van Schothorst, 1980) may be a better alternative.

Table 5. Chemical treatments of chicken carcasses

Treatment	Reference
5% lactic acid in water at 60-72 °C	Avens & Miller (1972)
3% succinic acid in water at 60-85 °C	Juven <i>et al.</i> (1974)
0.5% glutaraldehyde in chill water	Bailey <i>et al.</i> (1977)
6% phosphate in water at 60-90 °C	Thomson, Bailey & Cox (1979)
25 p.p.m. poly(hexamethylenebiguanide hydrochloride)	Thomson <i>et al.</i> (1981)
5% sodium chloride in water at 18 or 60 °C	Morrison & Fleet (1985)
2.5% potassium sorbate in water at 18 or 60 °C	Morrison & Fleet (1985)
1 mg/ml lysozyme and 5 mg/ml EDTA	Samuelson, Rupnow & Froning (1985)

Chilling of carcasses can be affected either by immersion in chilled water or by blasting with cold air. Within the EEC the former is designed primarily for use with birds for the frozen market and the latter for fresh birds.

Immersion chilling permits cross-contamination (Thomson *et al.* 1981) or reduces microbial numbers on carcasses (Mulder *et al.* 1976), depending on the mode of operation. Most processors in the UK add chlorine to chilling water (30-50 p.p.m.) and this can reduce both the numbers of salmonellas on infected carcasses and cross-contamination (Mead & Thomas, 1973). A properly run counter-flow immersion chiller with adequate chlorine levels can improve the microbiological quality of carcasses, including the elimination of salmonellas and the prolonging of shelf-life. This method, however, permits the uptake of water equivalent to approximately 4-5% of carcass weight which is not popular with consumers and the retail trade. Air-chilling, whether for fresh or frozen carcasses, even though it is not ideal for the latter, is becoming more popular. It affords less opportunity for cross-contamination, but the surface microbial counts on air-chilled birds can be higher than on those that have been immersion-chilled (Mead, 1975).

There have been various attempts to use chemicals to reduce carcass contamination. The most widely used of these has been chlorine and, as described above, it can help to reduce the microbial load on surfaces, carcasses and in chilling waters. Many other potentially effective treatments, however, can have an adverse effect on the appearance, odour or taste of the meat or leave undesirable residues.

The intensive nature of poultry slaughter militates against attempts to control or minimize carcass contamination. If salmonellas could be removed or destroyed at the end of processing, contamination and cross-contamination would become insignificant. Many workers have attempted to do this, and the data shown in Table 5 summarizes some of this work. While many treatments have proved successful in laboratory experiments, they have either not worked on a commercial scale or, as with hot succinic acid treatment, resulted in unacceptable carcass appearance.

One of the more effective end-product treatments is gamma-irradiation, and Dempster (1985) demonstrated that this process can destroy salmonellas on carcasses and prolong shelf-life.

Conclusions and prospects for future control

The data discussed in this review show that poultry meat continues to be a major vehicle of human salmonellosis, especially with respect to *S. typhimurium*, *S. enteritidis* and *S. virchow*. Within the last decade poultry production and processing has become progressively more efficient. These improvements appear, however, to have had no beneficial effect in reducing salmonella contamination of carcasses, which remains at a high level.

In view of the ubiquitous nature of salmonellas, involving widespread contamination of the environment and the well known cycles of transmission between the environment, animals and man, it seems unlikely that salmonellas could be entirely eradicated from farm animals, including poultry, by any cost-effective means. However, measures to break infection cycles, the production of salmonella-free feeds and more stringent control of farm hygiene would all reduce the incidence of salmonellas to more acceptable levels, provided that properly integrated control programmes could be implemented. If the number of carrier birds could be minimized, control measures in the slaughterhouse would have a better chance of reducing carcass contamination.

A more direct approach to the problem would be the treatment of processed carcasses with heat and/or chemicals to eliminate salmonellas prior to retail distribution. In fact, as discussed above, no entirely suitable treatment is presently available, apart from the use of ionizing radiation. Although the sale of irradiated foods is still prohibited in the UK, irradiation is widely recognized as a safe and effective process which does not impair the wholesomeness of the treated product. Should the ban be lifted, consumer resistance would appear to be the main barrier to commercial utilization of the process.

The remaining option is to increase public awareness of food poisoning hazards, particularly among those concerned with the handling and preparation of foods, especially poultry. This approach would necessitate intensive campaigns to provide relevant information and instruction, but it would ensure that the steps needed to make food safe in the kitchen are carried out more frequently and reliably, both in commercial enterprises and the home.

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