LACORS/HPA Co-ordinated Food Liaison Group Studies: Report on the Two Year Monitoring Study of Pathogens in Raw Meats, 2003-5

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On behalf of the Local Authorities Co-ordinators of Regulatory Services and the Health Protection Agency.

Summary

As part of the 2003/4 and 2004/5 LACORS/HPA Food Liaison Group Microbiological Sampling programmes, on-going surveillance of *Campylobacter* and *Salmonella* in raw meats was initiated with the aim of identifying the prevalence of these pathogens in raw meats. Of the 4340 raw meat samples examined from April 2003 to March 2005 red meat and poultry were more frequently contaminated with *Campylobacter* (10.6%) than with *Salmonella* (3.0%), and contamination was dependent on the type of meat. Raw chicken and game bird meat exhibited the highest contamination by *Campylobacter* (51.7% and 41.8%, respectively), followed by turkey (27.4%), other meats (19.0%), lamb (12.6%), pork (6.3%), beef (4.9%) and game meat (3.7%). In comparison, raw game bird meat exhibited the highest contamination by *Salmonella* (22.8%), followed by turkey (6.5%), chicken (5.8%), pork (3.9%), game meat (3.7%), lamb (2.0%), and beef (1.3%). Of the beef, lamb, and pork meat samples that were contaminated with *Campylobacter* or *Salmonella*, offal were more frequently contaminated than all other meat products.

Of the campylobacters isolated, *C. jejuni* predominated in all meat types with the exception of game bird meat. The most frequent serotypes of *C. jejuni* were HS4, HS13, HS50 and HS67, with HS13 and HS50 predominant in isolates from beef, pork, lamb and chicken samples. The predominant serotype of *C. coli* in raw meats was HS49. Of the 20 different *Salmonella* serotypes isolated from raw meats, *S.* Typhimurium was the most frequent serotype. In general, *C. coli* isolates from raw meats were more likely to exhibit multiple drug resistance, including quinolones, than *C. jejuni*. The antimicrobial resistance of *Salmonella* isolates differed according to the sero- and phage type of the organism with *S.* Typhimurium DT104/104b isolates exhibiting higher rates of multiple drug resistance than other serotypes. Such data profiles of *Campylobacter* and *Salmonella* in different types of raw meats can contribute to microbiological risk assessments by helping to assess the relative risks of cross contamination in the kitchen and of eating undercooked meats. The information can also be used over time to identify trends and help assess the effectiveness of current initiatives to improve hygiene and reduce bacterial loading at the on-farm primary production stages of food production. Since the end of this study, local authorities have been given new responsibilities for the enforcement of general hygiene controls under Annex 1 of Regulation (EC) No. 852/2004 at premises (farms etc) not previously subject to hygiene legislation.

Introduction

Reasons for Undertaking the Study

In terms of foodborne disease burden in England and Wales during 1992 to 2000 the most important pathogens include campylobacters and salmonellas[1]. In both catering and domestic kitchens raw meat is an important potential source of pathogenic bacteria and hence cross-contamination of ready-to-eat foods, particularly where the infective dose is low. This two year study contributes to important work aimed at identifying trends, seasonal variations and possible linkages between raw meat contamination levels and human illness. It is also hoped that some of the findings will be able to help assess the effectiveness of a range of industry and Food Standards Agency lead intervention strategies aimed at minimising pathogenic bacterial loading of raw meat.

The detailed aims of the exercise were outlined in the protocol and should help investigate a range of issues of significance in terms of public health (see aims and objectives below) as follows:

- Helping to study the nature and extent of cross-contamination in food premises between raw meat / and ready-to-eat foods in particular premises by linking unusual pathogens (e.g. rare serotypes, phagetypes, antimicrobial drug resistance profiles) with cases of human illness.
- Using the information from the study to help build up a picture of typical pathogens present on meat from different origins both from UK MHS plants and abroad.
- Providing information which might help future local authority investigations where unusual strains of bacteria can be used to help trace the possible origin and distribution of unlabelled meat.
- Helping to provide information and make appropriate recommendations to enforcement officers to assist them in relation to their task of ensuring food safety and protecting and public health.
- Using the information and experience gained in order to determine the requirements for further studies on this topic.

In addition to the above, the study could also be used to centrally gather data of a wider epidemiological and zoonotic significance:

- Although Defra sampling programmes regularly monitor zoonoses in live animals and much human epidemiological data is collated, little information is available concerning the microbiology of raw meat. This study may therefore provide valuable data for investigation of any linkages between raw meat, live animals and cases of human illness on a national basis.
- The study would generate information on antimicrobial drug resistance of pathogens isolated from raw meat which can then be compared with that found in pathogens isolated from food animals.
- The study might help investigate the transfer of bacteria across borders, and the extent to which meat imports may provide a vehicle for the introduction of unusual strains of bacteria to the UK. (If particular ‘imported bacteria’ are virulent or resistant to antibiotics there is a chance they could emerge as a public (and linked animal) health problem in the UK).

Background and Previous Studies

Campylobacters and salmonellas are known to colonise the intestines of farm animals and may contaminate meat of cattle, sheep, pigs, and poultry at the time of slaughter. Pathogenic microorganisms are therefore inherent constituents of raw meat and its products. In UK abattoirs during 2003 the carriage rate of *Salmonella* in pigs was 23.4%, whereas it was much lower in cattle (1.4%) and sheep (1.1%)[2]. A study of raw meats and poultry at retail sale in the UK during 1998 found that chicken exhibited the highest *Campylobacter* contamination rate (83%), followed by lamb (73%), pig (72%), and ox livers (54%)[3]. In 2001, a UK-wide survey 4% of raw fresh chicken sold at retail stores were contaminated with *Salmonella* spp. and 56% with *Campylobacter* spp.[4]. Contamination of meats with these pathogens can occur at multiple steps along the food chain, including production, processing, distribution, retail marketing, and handling or preparation. Raw meats and poultry are often identified as the source in food poisoning outbreaks[5,6]. One of the risk factors for human *Campylobacter* and *Salmonella* infection is the handling and contamination of raw meats and cross-contamination to ready-to-eat products[7].

Although *Campylobacter* or *Salmonella* infections are usually self-limiting and antibiotics are not required, severe cases may require treatment. The use of antimicrobial drugs in any environment creates selection pressures that favour the survival of antimicrobial drug resistant pathogens. The WHO reported that such organisms have become increasingly prevalent worldwide[8]. The routine practice of giving antimicrobial drugs in animal husbandry as a means of preventing and treating diseases is an important factor in the emergence of antimicrobial drug resistant bacteria that are subsequently transferred to humans through the food chain[9,10]. Most antimicrobial-resistant *Salmonella* infections are acquired from eating contaminated foods of animal origin[11]. Of particular importance since the late 1980s initially in the UK, then in Europe and several other countries worldwide, including the USA, has been a multiresistant strain of *S.* Typhimurium definitive phage type (DT) 104, displaying resistance to up to five commonly used antimicrobial drugs[12]. In England and Wales, multiresistance is also prevalent in *S.* Virchow and *S.* Hadar, whereas in other European countries multiple resistance is also found in other serotypes, such as *S*. Blockley[13]. Macrolides and ciprofloxacin may be used in some cases to treat campylobacter infections, and emerging resistance to these is a concern. Resistance to ciprofloxacin resistance continues to increase in both clinical isolates of *C. jejuni* and *C. coli*. In 2005, almost 30% of *C. jejuni* were resistant, whereas the figure for *C. coli* had risen to 45%[14].

Studies worldwide have shown that *Campylobacter* and *Salmonella* are often present in raw meat and poultry[15]. However, there is a scarcity of data concerning the prevalence of contamination with multiple foodborne pathogens, and their antimicrobial susceptibility profiles, in raw red meats in the UK. As part of the 2003/4 and 2004/5 LACORS/HPA Food Liaison Group Microbiological Sampling programmes, on-going surveillance of *Campylobacter* and *Salmonella* in retail raw meats began on 1 April 2003 with the aim of identifying the prevalence and types of these pathogens in raw meats and to investigate the association of microbial contamination with meat and product type, seasonality, country of origin, legal status, and storage and handling at the premises. Reported here are the results from the two year study.

Materials and Methods

Sample Collection

Samples of fresh chilled raw red meats and poultry collected from food premises were examined in HPA, HPA collaborating and non-HPA laboratories in the UK between the 1st April 2003 and 31st March 2005 using a standardised protocol. Sausages, burgers, meats with added ingredients (seasoning, marinade) and fresh frozen raw meats were specifically excluded from the study. Samples (≥100g) were collected by staff from local authority Environmental Health Departments and were transported to the laboratory in accordance with the Food Safety Act 1990 Code of Practice[16] and advice provided in LACORS guidance on microbiological food sampling[17].

Information on the raw meat and poultry samples and premises was obtained by observation and enquiry and recorded on a standard proforma. This included information on the type of raw meats and how they were produced, packaged, display temperature, legal status, and the country of origin. Raw meats judged by the sampling officer to be legal were those that complied with food safety legislation, whereas meats judged to be illegal were those that did not (including unfit meat) or were illegally imported.

Sample Preparation

For raw meats and poultry portions, two representative (~25g) sub-samples from the raw meat or poultry portions sample were required for microbiological examination. For whole birds, a neck-skin sample (25g) was aseptically removed from each poultry carcass and placed in individual stomacher bags (~180mm x 300mm). The carcass-rinse was prepared by rinsing the chicken, after removal of the neck-skin, in Buffered Peptone Water (BPW, 300ml) for 1 minute in a stomacher bag (~380 x 515mm) ensuring contact of the BPW with all poultry surfaces. Carcass-rinse samples were then poured into the smaller stomacher bag containing the neck-skin and homogenised for 2 minutes. Twenty-five millilitre samples of this homogenate were then removed into 225ml Bolton Selective Enrichment Broth for enrichment of *Campylobacter* spp. The remaining homogenate contents were placed into a sterile plastic container for enrichment of *Salmonella* spp.

Sample Examination

Detection of *Salmonella* spp. was carried out in accordance with the HPA Standard Microbiological Method[18]. C*ampylobacter* spp. were detected by enrichment in Bolton Selective Enrichment Broth with incubation at 37°C for 4 hours, followed by further incubation at 41.5°C and subculture to *Campylobacter* selective agar (CCDA) after 44 $\pm$ 2 h. Inoculated plates were incubated at 41.5°C for 48 h, and colonies identified as described in HPA Standard Microbiological Method F21[19]. Isolates of *Campylobacter* spp. and *Salmonella* spp. were sent to the Laboratory of Enteric Pathogens (LEP) at the HPA Centre for Infections, for sero- and phage typing and determination of susceptibility to antimicrobial drugs. Isolates were tested for sensitivity to antimicrobial drugs using breakpoint methods[20,21].

Results

A total of 4340 raw meat samples were examined over two years in 35 laboratories (HPA or HPA Collaborating, NPHS-Wales, Public Analysts) in England, Wales, Scotland and Northern Ireland. Samples were submitted by 295 Local Authorities, involving 51 Local Authority Food Liaison Groups (Annex 1).

Prevalence of *Campylobacter* and *Salmonella* in raw meat and poultry

Of the types of raw meats sampled (4340) most were beef (36.0%), pork (33.2%) and lamb (20.8%) (Table 1). Significantly *Campylobacter* spp. were detected in a greater proportion of raw meats (10.6%; 460) than that of *Salmonella* spp. (3.0%; 132) ($p<0.0001$) (Table 1). Fifty-nine (1.4%) samples (pork (19), game bird meat (14), beef (13), chicken (6), lamb (5), turkey (1), game meat (1)) were found to have both *Salmonella* and *Campylobacter* present.

Raw chicken and game bird meat exhibited the highest contamination by *Campylobacter* (51.7% and 41.8%, respectively), followed by turkey (27.4%), other meats (e.g. mutton; 19.0%), lamb (12.6%), pork (6.3%), beef (4.9%), and game meat (3.7%) (Table 1). This finding was significant when comparing raw chicken and game bird meat to beef, pork, lamb, and game meat ($p<0.0001$). With regard to red meats, lamb and other meats (e.g. mutton) exhibited the highest contamination by *Campylobacter* (12.6% and 19.0%, respectively), followed by pork (6.3%), beef (4.9%) and game meat (3.7%) (Table 1). This finding was significant when comparing raw lamb and other meats to pork ($p<0.0001$) and beef ($p=0.0277$), respectively. Neither *Campylobacter* nor *Salmonella* were detected from goat meat samples, although only a very few of these samples were tested (Table 1).

Game bird meat exhibited the highest contamination by *Salmonella* (22.8%), followed by turkey (6.5%), chicken (5.8%), pork (3.9%), game meat (3.7%), lamb (2.0%), and beef (1.3%) (Table 1). This finding was significant when comparing game bird meat to chicken, turkey, beef, pork, lamb, game meat ($p<0.0001$) (Table 1). With regard to red meats, pork and game meat exhibited the highest contamination by *Salmonella* (3.9% and 3.7%, respectively), followed by lamb (2.0%), and beef (1.3%) (Table 1). This finding was significant when comparing pork to beef ($p<0.0001$) and lamb ($p=0.0106$) (Table 1).

Table 1. Prevalence of *Campylobacter* and *Salmonella* in raw meats (n=4340)

Meat type	No. samples (%)		Samples with *Salmonella* (%)		Samples with *Campylobacter* (%)	
Beef	1563	(36.0%)	21	(1.3%)	77	(4.9%)
Pork	1440	(33.2%)	56	(3.9%)	90	(6.3%)
Lamb	905	(20.8%)	18	(2.0%)	114	(12.6%)
Chicken	240	(5.5%)	14	(5.8%)	124	(51.7%)
Turkey	62	(1.5%)	4	(6.5%)	17	(27.4%)
Game bird meat	79	(1.8%)	18	(22.8%)	33	(41.8%)
Game meat	27	(0.6%)	1[†]	(3.7%)	1[†]	(3.7%)
Goat	3	(0.1%)	0		0	
Other (mutton, veal, water buffalo, zebra)	21	(0.5%)	0		4[§]	(19.0%)
Total	4340		132	(3.0%)	460	(10.6%)

†; rabbit, §; mutton

The prevalence of *Campylobacter* and *Salmonella* in raw meats also varied according to the type of raw meat product (Table 2). Of the beef, lamb, and pork meat samples that were contaminated with *Campylobacter*, offal (12.2% to 36.6%) were more frequently contaminated than all other meat products (3.3% to 10.0%) (Table 2). This finding was significant when comparing lamb and pork offal to all other lamb and pork products, respectively ($p<0.0001$). In the case of beef offal, this finding was only significant when comparing beef offal to whole muscle cuts ($p=0.0281$). Although represented in comparatively low numbers, the proportion of

mutton chops with *Campylobacter* present (66.7%) was higher when compared to all other meat and poultry products (3.3% to 55.9%) (Table 2).

Likewise, of the beef, lamb, and pork meat samples that were contaminated with *Salmonella*, offal were more frequently contaminated with *Salmonella* (6.1%, 3.1%, 23.6%, respectively) compared to other beef, lamb and pork product samples (Table 2). This finding was significant when comparing pork offal to all other pork ($p<0.0001$), and beef offal to whole muscle cut ($p=0.0264$).

Table 2. Prevalence of *Campylobacter* and *Salmonella* in raw meat products

Meat type	Meat product	No. samples (%)		Samples with *Salmonella* (%)		Samples with *Campylobacter* (%)	
Beef (n=1563)	Whole muscle cut	1350	(86.4%)	16	(1.2%)	61	(4.5%)
	Joint	75	(4.8%)	2	(2.7%)	7	(9.3%)
	Offal (liver, heart, kidney, oxtail, tripe)	49	(3.2%)	3	(6.1%)	6	(12.2%)
	Other (diced)	89	(5.7%)	0		3	(3.3%)
Lamb (n=905)	Whole muscle cut	214	(23.7%)	3	(1.6%)	17	(7.9%)
	Joint	78	(8.6%)	0		6	(7.7%)
	Chops	432	(47.7%)	10	(2.3%)	30	(6.9%)
	Offal (liver, heart, kidney)	161	(17.8%)	5	(3.1%)	59	(36.6%)
	Other (diced)	20	(2.2%)	0		2	(10.0%)
Pork (n=1440)	Whole muscle cut	477	(33.1%)	7	(1.5%)	28	(5.9%)
	Joint	83	(5.8%)	4	(4.8%)	8	(9.6%)
	Chops	729	(50.6%)	14	(1.9%)	28	(3.8%)
	Offal (liver, heart, kidney, tripe)	131	(9.1%)	31	(23.6%)	23	(17.5%)
	Other (diced)	20	(1.4%)	0		2	(10.0%)
Chicken (n=240)	Whole bird	31	(12.9%)	4	(12.9%)	10	(32.3%)
	Portions	202	(84.2%)	10	(4.9%)	113	(55.9%)
	Offal (livers, heart)	7	(2.9%)	0		1	(14.2%)
Turkey (n=62)	Whole bird	2	(3.2%)	0		1	(50.0%)
	Portions	58	(96.6%)	4	(6.9%)	15	(25.8%)
	Other (diced)	2	(3.2%)	0		1	(50.0%)
Game bird meat (n=79)*	Whole bird	21	(26.6%)	4	(19.0%)	9‡	(42.8%)
	Portions	58	(73.4%)	14	(22.1%)	24§	(41.3%)
Game meat (hare, rabbit, venison) (n=27)	Whole muscle cut	23	(85.2%)	1†	(5.9%)	1†	(5.9%)
	Offal (kidney)	1	(3.7%)	0		0	
	Other (Whole rabbit, hare)	3	(11.1%)	0		0	
Goat (n=3)	Whole muscle cut	2	(50.0%)	0		0	
	Joint	1	(50.0%)	0		0	
Other (mutton, veal, water buffalo, zebra) (n=21)	Whole muscle cut	15	(71.4%)	0		1¶	(6.7%)
	Joint	1	(4.8%)	0		0	
	Chops	3	(14.3%)	0		2¶	(66.7%)
	Other (diced)	2	(9.5%)	0		1¶	(50.0%)

*, duck (67%; 53), ostrich (9%; 7), wood pigeon (9%; 7), pheasant (5%; 4), partridge (3%; 2), poussin (3%; 3), quail (3%; 2), guinea fowl (1%; 1);
‡, 2/9 duck, 2 partridge, 1 ostrich, 1 wood pigeon, 1 pheasant, 1 poussin, 1 quail, 1 guinea fowl;
§ 23/24 duck, 1/23 guinea fowl
†; rabbit, ¶; mutton

Of the poultry meat samples that were contaminated with *Campylobacter*, chicken portions (55.9%) and whole and portions of game bird meat (42.8% and 41.3%, respectively) were more frequently contaminated than whole chickens (32.3%). This finding was only significant when comparing chicken portions to whole chicken (p=0.0195). In contrast, turkey portions were less frequently contaminated with *Campylobacter* (25.8%). Whole and diced meat turkey samples appeared to have a high prevalence of *Campylobacter* (50%), although these samples were represented in comparatively very low numbers (Table 2).

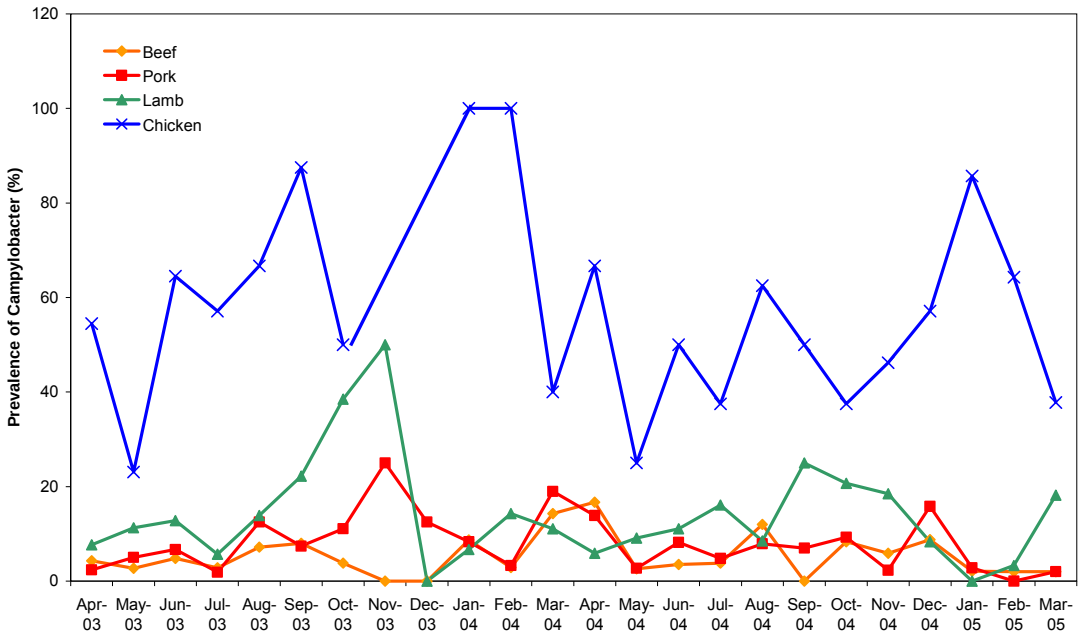
Quite the opposite to the prevalence of *Campylobacter* found in raw chicken, whole chicken (12.9%) were more frequently contaminated with *Salmonella* than portions of chicken (4.9%) (Table 2). Whereas, in game meat samples, portions were found to be more frequently contaminated with *Salmonella* (22.1%) compared to whole birds (19.0%). *Salmonella* was only detected in turkey portions (6.9%) (Table 2). These differences were not found to be significantly different.

Seasonal variation in prevalence of *Campylobacter* and *Salmonella* in raw meats

Looking at seasonal variation from April 2003 to March 2005 in the prevalence of *Campylobacter* and *Salmonella,* the monthly variations are shown in Figures 1 and 2 for beef, pork, lamb and chicken samples. There were insufficient samples collected overall for the other meat types to assess seasonal variation.

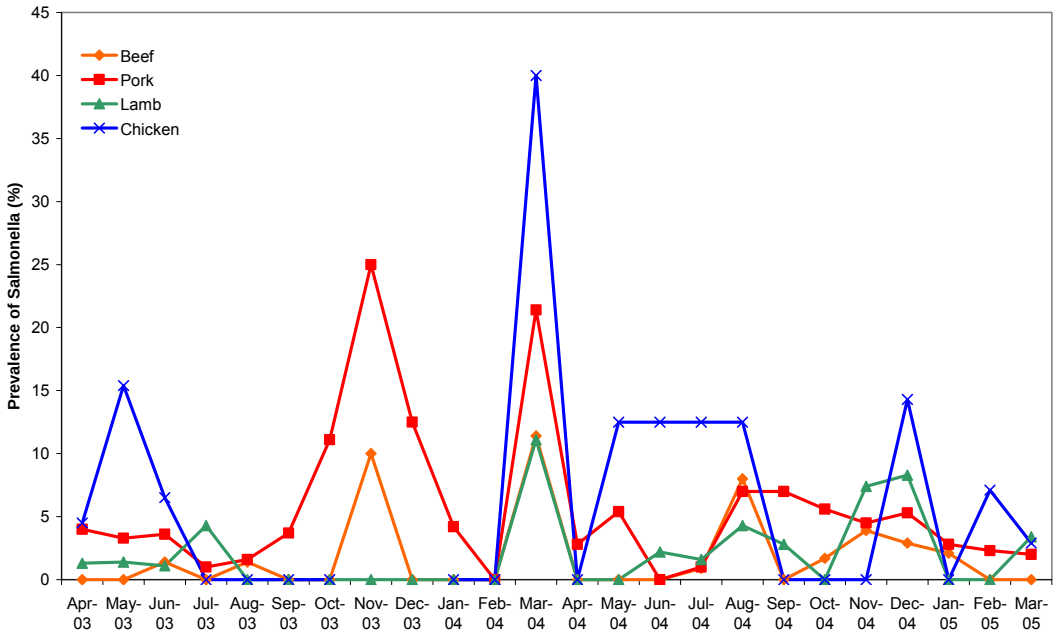
The prevalence of *Campylobacter* in raw beef, pork, lamb and chicken samples varied throughout the two year sampling period (Fig. 1). For beef, pork and chicken samples there appeared to be no obvious seasonal peaks. For lamb samples, a seasonal effect was observed, with an upwards trend from August with a decline seen in winter months (December/January).

Fig. 1 Monthly variation in prevalence of *Campylobacter* in raw fresh meats, April 2003 to March 2005



The prevalence of *Salmonella* in raw beef, pork, lamb and chicken samples varied widely throughout the two year sampling period (Fig. 2). For example, although the prevalence of salmonella in pork samples peaked in November 2003 and again at March 2004, these peaks in salmonella prevalence was not seen in the following year.

Fig. 2 Monthly variation in prevalence of *Salmonella* in raw fresh meats, April 2003 to March 2005



Campylobacter isolate types

Of the 354 *Campylobacter* isolates that were further characterized for raw meat samples:

- 63.5% (225) were *C. jejuni*
- 29.9% (106) were *C. coli*
- 4.5% (16) were mixed, i.e. *C. jejuni* and *C. coli*
- 0.9% (3) were *C. lari*
- 0.9% (3) were *C. fetus*
- 0.3% (1) was *C. lanienae*.

C. jejuni predominated in all meat types with the exception of game bird meat (Table 3). In addition, *C. lari* was identified from two samples of turkey and one of lamb, *C. fetus* from two samples of lamb and one of pork, and *C. lanienae* was identified from a single sample of pork.

A breakdown of HS-serotypes among *C. jejuni,* and *C. coli* isolates is provided in Table 3. There were a total of 28 and 13 HS-serotypes of *C. jejuni* and *C. coli*, respectively. The most frequent serotypes of *C. jejuni* were HS4, HS13, HS50 and HS67, which accounted for 12 (5.3%), 11 (4.9%), 16 (7.1%) and 14 (6.2%) of the 225 *C. jejuni* isolates, respectively. *C. jejuni* HS4, 13, 50 and 67 were all common to beef and pork. *C. jejuni* HS4, 13, and 50 were also common to lamb, and HS 13, 50, and 67 to chicken. The most frequent serotype of *C. coli* was HS49, which accounted for

24 (22.6%) of the 106 *C. coli* isolates. *C. coli* HS49 were common to beef, pork, lamb, chicken, turkey and game bird meat.

Table 3. Distribution of *C. jejuni* and *C. coli* serotypes between raw meat types

Meat type	No. isolates	*C. jejuni* (%)		*C. jejuni* HS-serotype (No. isolates)	*C. coli* (%)		*C. coli* HS-serotype (No. isolates)
Beef	49	43	(87.7%)	1 (1), 2 (1), 4 (2), 8 (1), 9 (2), 13 (2), 18 (2), 27 (1), 37 (5), 43 (1), 50 (4), 55 (1), 62 (1), 63 (2), 67 (4), UT (13)	6	(12.3%)	9 (1), 28 (1), 49 (1), 58 (1), *UT (2)
Pork	68	36	(52.9%)	1 (1), 2 (1), 4 (3), 8 (2), 9 (1), 13 (2), 23 (3), 29 (1), 35 (3), 43 (1), 50 (1), 60 (1), 67 (4), UT (12)	32	(47.1%)	9 (3), 14 (2), 24 (1), 28 (1), 39 (1), 49 (3), 56 (1), 59 (4), 66 (5), UT (12)
Lamb	90	64	(71.1%)	1 (1), 2 (6), 4 (7), 6 (1), 9 (2), 11 (1), 12 (1), 13 (3), 23 (1), 31 (1), 50 (9), 55 (1), 63 (1), 68 (3), UT (26)	26	(28.9%)	9 (2), 26 (1), 28 (1), 39 (1), 49 (11), 56 (1), 59 (2), UT (7)
Chicken	89	64	(71.9%)	1 (2), 6 (1), 8 (1), 9 (1), 11 (1), 13 (4), 18 (2), 19 (1), 27 (1), 37 (4), 44 (1), 50 (1), 57 (2), 60 (3), 63 (2), 67 (5), UT (18), ND (14)	25	(28.1%)	9 (2), 14 (1), 25 (1), 28 (1), 49 (3), 56 (2), 59 (1), 66 (1), UT (8), ND (5)
Turkey	11	6	(54.6%)	9 (1), 18 (1), 50 (1), 60 (1), ND (2)	5	(45.4%)	49 (2), 56 (1), UT (2)
Game bird meat	20	9	(45.0%)	27 (2), UT (7)	11	(55.0%)	9 (2), 49 (4), 56 (2), 59 (2), UT (1)
Game meat	2	2	(100%)	UT (1)	0		
Other (mutton, veal, water buffalo)	2	1	(50.0%)	67 (1)	1	(50.0%)	24 (1)
Total	331	225	(68.0%)		106	(32.0%)	

*UT, untypeable
ND, serotyping not done

The microbial drug resistance of *C. jejuni* and *C. coli* isolates is outlined in Table 5. *C. jejuni* and *C. coli* isolates all have resistance to trimethoprim and as this is generally used in selective medium for these organisms, resistance to trimethoprim was excluded from the analysis presented in Table 5. Higher frequencies of resistance in *C. jejuni* isolates were observed among the pork isolates (80.6% overall; 22.2% exhibited multiple resistance (MR) to four or more antimicrobial drugs), while isolates from lamb samples exhibited a lower frequency of resistance at 28.1% (6.3% MR) (Table 5). Although the number of *C. jejuni* strains isolated from turkey and game bird meat was small, 83.3% (16.7% MR) and 88.9% respectively of these were found to have resistance to antimicrobial drugs.

Of the *C. coli* isolates, higher frequencies of resistance were again observed among the pork isolates (87.5% overall; 21.9% exhibited MR), while isolates from chicken samples exhibited a lower frequency of resistance (68%) but had a higher MR of

24.0% (Table 5). Although the number of *C. coli* strains isolated from turkey and game bird meat was small, 100% (60.0% MR) and 72.7% (45.5% MR) respectively of these were found to have resistance.

Resistance to erythromycin and the quinolones nalidixic acid and ciprofloxacin was more frequent in *C. coli* than in *C. jejuni* isolates obtained from raw beef, lamb, pork, turkey, chicken and game bird meat (Table 5). Of the *C. coli* isolates 16.7% to 60.0% were resistant to nalidixic acid and ciprofloxacin compared with *C. jejuni* isolates where 0% to 27.8% were resistant to nalidixic acid and 0% to 19.4% resistant to ciprofloxacin.

Table 5. Microbial drug resistance of *C. jejuni* and *C. coli* isolated from raw meat

Meat	*Campylobacter*	No. isolates	%AR[a]	%MR[b]	Percentage (%) of isolates resistant to antimicrobial drug[c]									
					A	C	T	F	G	K	Ne	Nx	Cp	E
Beef	*C. jejuni*	43	65.1	16.2	44.2	2.3	48.8	2.3	2.3	0	0	13.9	11.6	0
	C. coli	6	83.3	0	66.7	0	33.3	0	0	0	0	16.7	16.7	16.7
Lamb	*C. jejuni*	64	28.1	6.3	18.8	0	14.1	0	0	1.6	1.6	12.5	10.9	0
	C. coli	26	73.1	19.2	46.1	3.8	34.6	0	0	0	0	26.9	23.1	23.1
Pork	*C. jejuni*	36	80.6	22.2	72.2	16.7	55.6	0	0	8.3	8.3	27.8	19.4	8.3
	C. coli	32	87.5	21.9	40.7	6.3	59.4	0	0	6.3	6.3	37.5	28.1	40.6
Turkey	*C. jejuni*	6	83.3	16.7	66.7	0	83.3	0	0	0	0	16.7	16.7	16.7
	C. coli	5	100	60.0	60.0	0	80.0	0	0	0	0	60.0	60.0	80.0
Chicken	*C. jejuni*	64	75.0	11.0	57.8	1.5	46.9	1.5	1.5	4.7	4.7	11.0	9.4	1.5
	C. coli	25	68.0	24.0	52.0	12.0	48.0	0	0	4.0	4.0	40.0	36.0	4.0
Game bird	*C. jejuni*	9	88.9	0	66.7	0	77.8	0	0	0	0	0	0	0
	C. coli	11	72.7	45.5	45.5	0	54.6	0	0	9.0	9.0	54.6	54.6	36.3
Game meat	*C. jejuni*	2	100	0	50.0	0	100	0	0	0	0	0	0	0
	C. coli	0						0						
Mutton	*C. jejuni*	1	100	0	100	0	0	0	0	0	0	0	0	0
	C. coli	1	100	0	100	0	0	0	0	0	0	0	0	0

a %AR, percentage of isolates from each meat resistant to one or more antimicrobial drugs
b %MR, percentage of multiresistant isolates (isolates resistant to four or more antimicrobial drugs) from each meat
c Key to antimicrobial drugs: A, ampillicin; C, chloramphenicol; T, tetracycline; F, furazolidone; G, gentamicin; K, kanamycin; Ne, neomycin; Nx, nalidixic acid; Cp, ciprofloxacin; E, erythromycin

Salmonella isolate types

A breakdown of the 20 named *Salmonella* serotypes isolated from raw meats is provided in Table 6. *S.* Typhimurium was the most frequent serotype, accounting for 44.0% of the referred 116 isolates. Of the 51 *S*. Typhimurium isolates, 24 (47.1%) were phage typed as either definitive phage type (DT) 104 or DT 104b. *S*. Derby was the second most frequent serotype, accounting for 12.9% (15) of the isolates (Table 6).

Table 6 also provides a breakdown of the *Salmonella* sero- and phage types by type of meat. Most *S.* Typhimurium isolates (88.2%) were obtained from red meats (pork (51.0%), lamb (21.6%), beef (15.7%) but *S.* Typhimurium DT 8 and DT 99 were only obtained from game bird meat (duck) samples. Similarly most *S*. Derby isolates (93.3%) were obtained from red meats, whereas all *S*. Enteritidis isolates were obtained from chicken.

Table 6. Sero- and phage types of *Salmonella* isolated from raw meats

Serotype	Phage Type*	No. isolates	Meat type
S. Typhimurium	DT 8	2	Game bird meat (2, duck)
(n=51)	DT 12	4	Lamb (3), pork (1)
	DT 99	3	Game bird meat (3, duck)
	DT 104	19	Pork (9), beef (5), lamb (4), turkey (1)
	DT 104b	5	Pork (4), beef (1)
	DT 120	2	Pork (2)
	DT 193	1	Pork
	DT 208	3	Pork (3)
	PT U302	4	Pork (2), lamb (2)
	PT U310	3	Pork (3)
	PT U311	2	Beef (2)
	UT	3	Lamb (2), pork (1)
S. Enteritidis (n=8)	PT 1	1	Chicken
	PT 4	3	Chicken (3)
	PT 6a	2	Chicken (2)
	PT 8	1	Chicken
	PT 21	1	Chicken
S. Agona	PT 3	1	Pork
	P T7	1	Chicken
S. Arizonae	-	2	Lamb (1), pork (1)
S. Cholerae-Suis	-	1	Pork
S. Derby	-	15	Pork (8), beef (3), lamb (3), turkey (1)
S. Dublin	-	1	Beef
S. Hadar	PT 62	1	Game bird meat (duck)
S. Indiana	-	5	Game bird meat (5, duck)
S. Infantis	-	1	Chicken
S. Java	-	1	Chicken
S. Kedougou	-	2	Chicken (1), pork (1)
S. Kottbus	-	4	Game bird meat (3, duck), turkey (1)
S. Mbandaka	-	1	Beef
S. Muenster	-	1	Beef
S. Newport	-	3	Pork (3)
S. Ohio	-	1	Chicken
S. Saint-Paul	-	1	Turkey
S. Senftenberg	-	1	Game bird meat (duck)
S. Stanleyville	-	1	Pork
S. Unnamed	-	13	Pork (8), beef (3), Chicken (1), lamb (1)

*DT, definitive phage type; PT, phage type; UT, untypeable

Of the 116 isolates, 26 (22.4%) were sensitive to all of the antimicrobial drugs tested (Tables 7a and 7b). The proportion of sensitive strains varied between serotypes and between phage types within a serotype. Multiple resistance, i.e. resistance to four or more unrelated antimicrobial drugs, was found in 48 (41.4%) of the isolates, of which most were *S*. Typhimurium DT 104/104b (41.7%; 20) and *S*. Typhimurium phage type (PT) 302 (9.2%; 4) (Tables 7a and 7b).

Of the *Salmonella* isolates obtained from red meats, *S*. Typhimurium isolates generally exhibited greater multiple resistance to four or more antimicrobial drugs compared to other named serotypes (Table 7a). Only one (12.5%) of the *S*. Enteritidis isolates obtained from chicken exhibited multi-drug resistance (Table 7b). Although in small numbers, isolates of *S.* Saint-Paul and Typhimurium DT 8 obtained from two turkey samples, *S.* Java obtained from one chicken sample, and *S.* Hadar and Typhimurium from two game bird meat samples also exhibited multiple resistance (Table 7b).

For individual antimicrobial drugs, the most frequent resistance found in *Salmonella* isolates obtained from red meats was to tetracyclines (67.5%), sulphonamides (56.6%), streptomycin (50.6%), ampicillin (43.4%), spectinomycin (43.4%), chloramphenicol (33.7%), and trimethoprim (18.1%) (Table 7a).

Table 7a. Microbial drug resistance of *Salmonella* isolated from raw red meat

Meat	Salmonella	No. isolates	%AR[a]	%MR[b]	Percentage (%) of isolates resistant to antimicrobial drug[c]												
					A	C	S	Su	Sp	T	Tm	G	K	Ne	Nx	Cp	Cp_L
Beef	*S.* Typhimurium																
	- DT 104	5	100	60	60	60	100	100	100	60	0	0	0	0	0	0	0
	- DT 104b	1	100	0	0	0	100	100	100	0	0	0	0	0	0	0	0
	- PT U311	2	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0
	S. Derby	3	100	33.3	0	0	33.3	33.3	33.3	100	33.3	0	0	0	0	0	0
	S. Dublin	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Mbandaka	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Muenster	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Unnamed	3	100	66.7	66.7	0	66.7	66.7	0	66.7	0	0	0	0	0	0	0
Lamb	*S.* Typhimurium																
	- DT 12	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- DT 104	4	100	100	100	100	100	100	100	100	0	0	0	0	50	-	50
	- PT U302	2	100	100	100	100	100	100	100	100	0	0	0	100	100	-	100
	- UT	2	100	100	100	0	100	100	0	100	0	0	0	0	0	0	0
	S. Arizonae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Derby	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Unnamed	1	100	100	0	0	100	100	100	0	100	0	0	0	0	0	0
Pork	*S.* Typhimurium																
	- DT 12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- DT 104	9	100	100	100	100	100	100	100	100	0	0	0	0	33.3	-	33.3
	- DT 104b	4	100	100	75	50	100	100	100	100	75	0	0	0	0	0	0
	- D T120	2	100	50	50	0	50	50	50	50	50	0	0	0	0	50	-
	- DT 193	1	100	100	100	0	100	100	0	100	100	0	100	100	0	0	0
	- DT 208	3	100	0	0	0	0	0	0	100	0	0	0	0	0	0	0
	- PT U302	2	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0
	- PT U310	3	100	33.3	33.3	33.3	0	0	0	100	0	0	0	33.3	0	33.3	-
	- UT	1	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0
	S. Agona PT 3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Arizonae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Cholerae-Suis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Derby	8	100	12.5	0	0	12.5	25	12.5	100	12.5	0	0	0	0	0	0
	S. Kedougou	1	100	0	0	0	0	100	0	100	100	0	0	0	0	0	0
	S. Newport	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Stanleyville	1	100	0	0	0	0	100	0	0	100	0	0	0	0	0	0
	S. Unnamed	8	75	50	37.5	25	37.5	62.5	25	62.5	25	0	0	0	0	0	0

a %AR, percentage of isolates from each meat resistant to ≥1 antimicrobial drugs; b %MR, percentage of multiresistant isolates (isolates resistant to ≥4 antimicrobial drugs) from each meat
c Key to antimicrobial drugs: A, ampillicin; C, chloramphenicol; S, streptomycin; Su, sulphonamides; Sp, spectionmycin; T, tetracyclines; Tm, trimethoprim; G, gentamicin; K, kanamycin; Ne, neomycin; Nx, nalidixic acid; Cp, ciprofloxacin (MIC: >1 mg/l); Cp_L, low susceptibility to ciprofloxacin (MIC: 0.125 – 1.0 mg/l).

Table 7b. Microbial drug resistance of *Salmonella* isolated from raw poultrymeat

Meat	Salmonella	No. isolates	%AR[a]	%MR[b]	Percentage (%) of isolates resistant to antimicrobial drug[c]												
					A	C	S	Su	Sp	T	Tm	G	K	Ne	Nx	Cp	Cp_L
Turkey	*S.* Derby	1	100	0	0	0	100	100	0	100	0	0	0	0	0	0	0
	S. Kottbus	1	100	0	0	0	0	0	0	100	0	0	0	0	0	0	0
	S. Saint-Paul	1	100	100	100	100	100	100	100	0	0	100	100	100	100	-	100
	S. Typhimurium - DT 104	1	100	100	100	0	100	100	100	0	0	100	100	0	100	-	100
Chicken	*S.* Enteritidis																
	- PT 1	1	100	0	0	0	0	0	0	0	0	0	0	0	100	-	100
	- PT 4	3	33.3	33.3	33.3	33.3	0	0	0	0	33.3	33.3	0	0	33.3	0	0
	- PT 6a	2	100	0	50	0	0	0	0	50	50	0	0	0	50	-	50
	- PT 8	1	100	0	0	0	0	0	0	0	0	0	0	0	100	-	100
	- PT 21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Agona PT 7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Infantis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Java	1	100	100	0	0	100	0	100	0	100	0	0	0	100	-	100
	S. Kedougou	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Ohio	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Unnamed	1	100	100	0	0	0	100	0	100	100	100	0	0	0	0	0
Game bird meat	*S.* Hadar PT 62	1	100	100	0	0	100	0	0	100	0	0	0	0	100	-	100
	S. Indiana	5	100	0	0	0	0	100	0	100	100	0	0	0	0	0	0
	S. Kottbus	3	100	0	33.3	0	0	0	0	0	0	0	0	0	66.7	0	0
	S. Senftenberg	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S. Typhimurium																
	- DT 8	2	100	50	0	0	100	100	100	50	50	0	0	0	0	0	0
	- DT 99	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

a %AR, percentage of isolates from each meat resistant to ≥1 antimicrobial drugs;
b %MR, percentage of multiresistant isolates (isolates resistant to ≥4 antimicrobial drugs) from each meat
c Key to antimicrobial symbols: see Table 7a.

Raw Meat Product Information

Production Method

Most (96.6%) of the samples collected were not organically produced, while 1.9% were produced using organic farming methods (Table 8). The incidence of *Campylobacter* detected in raw meats produced organically or not was 8.4% and 10.5%, respectively. *Salmonella* was only detected in raw meats that were not produced organically (2.7%) (Table 8). However, it should be noted that the proportion of samples organically produced was very small and that no statistical conclusions should be drawn from these results.

Over half (54.1%) of samples were open or unwrapped when sampled and 44.5% were prepacked (Table 8). There was no significant difference in the incidence of *Campylobacter* or *Salmonella* detected between raw meats that were packed or open (Table 8).

Thirty eight percent of samples had a health mark, 44.6% did not and for 18.2% of samples, this information was not recorded (Table 8). There was no significant difference in the incidence of *Campylobacter* or *Salmonella* detected between raw meat with or without a healthmark (Table 8).

Most (96.8%) samples were legal (Table 8). There was no significant difference in the incidence of *Campylobacter* or *Salmonella* detected between raw meat of legal or illegal status (Table 8).

Table 8. Prevalence of *Campylobacter* and *Salmonella* in raw meat products in relation to production and packaging

Meat Sample (n=4340)	No. samples (%)		Samples with *Salmonella* (%)		Samples with *Campylobacter* (%)	
Organic						
Yes	83	(1.9%)	0		7	(8.4%)
No	4192	(96.6%)	130	(3.1%)	442	(10.5%)
Not recorded	65	(1.5%)	2	(3.1%)	11	(16.9%)
Packaging						
Wrapped/Packed	1933	(44.5%)	63	(3.3%)	205	(10.6%)
Open/Unwrapped	2347	(54.1%)	65	(2.8%)	247	(10.5%)
Not recorded	60	(1.4%)	4	(6.7%)	8	(13.3%)
Healthmark						
Yes	1632	(37.6%)	57	(3.5%)	194	(11.9%)
No	1914	(44.1%)	48	(2.5%)	180	(9.4%)
Not recorded	794	(18.3%)	27	(3.4%)	86	(10.8%)
Legal status						
Legal	4201	(96.8%)	130	(3.1%)	450	(10.7%)
Illegal	41	(1.0%)	1	(2.4%)	4	(9.6%)
Not recorded	98	(2.2%)	1	(1.0%)	6	(6.1%)

Of the 4043 raw meats sampled most (83.0%) were produced in the UK, and 11.3% of samples were produced in other EU or Third countries (non-EU). The importation status or country of origin was not known for 5.7% of samples (Table 9). There was no significant difference in the incidence of *Campylobacter* or *Salmonella* detected between raw meats that were produced in the UK or elsewhere (Table 9).

Table 9. Prevalence of *Campylobacter* and *Salmonella* in raw meat products in relation to country of origin

Country of Origin	No. samples (%)		Samples with *Salmonella* (%)		Samples with *Campylobacter* (%)	
UK	3602	(83.0%)	113	(3.1%)	391	(10.9 %)
Other EU Member States	289	(6.7%)	11	(3.8%)	29	(10.0%)
- Belgium	35		0		3	
- Denmark	20		1		1	
- France	22		4		8	
- Germany	19		4		1	
- Hungary	1		1		0	
- Netherlands	50		1		9	
- Poland	3		0		0	
- Republic of Ireland	133		0		3	
- Spain	3		0		0	
- Sweden	3		0		0	
Third Countries	199	(4.6%)	2	(1.0%)	21	(10.6%)
- Argentina	17		0		2	
- Australia	16		0		0	
- Botswana	3		1		0	
- Brazil	33		0		0	
- Chile	1		0		0	
- China	1		0		0	
- Iceland	4		0		0	
- Isle of Man	1		0		1	
- New Zealand	114		1		18	
- Uruguay	9		0		0	
Not known	250	(5.7%)	6	(2.4%)	23	(9.2%)
Total	4340		132	(3.0%)	460	(10.6%)

Type of premises and storage and handling raw meats

Most samples collected were from licensed butchers (44.8%) and supermarkets (38.6%). Other samples were mostly collected from non-licensed butcher shops (5.4%), market stalls (2.4%), restaurants (2.4%) and public houses (2.2%) (Table 10).

The prevalence of *Campylobacter* and *Salmonella* in raw meats varied according to the type of premises (Table 10). Of the samples that were contaminated with *Campylobacter* those collected from farm shops and other premises such as convenience stores and hotels exhibited the lowest contamination by *Campylobacter* (1.7 - 1.9%) compared to other premises types (5.0% to 14.3%) (Table 10). However samples collected from farm shops and premises such as convenience stores and hotels were represented in comparatively low numbers compared to those collected from premises such as supermarkets and butcher shops, and that no statistical conclusions should be drawn from these results.

Of the samples that were contaminated with *Salmonella,* those collected from market stalls exhibited the lowest contamination from *Salmonella* (1.0%) compared to those from other premises types (1.9% to 3.2%) (Table 10). These differences were not found to be significant.

Table 10. Prevalence of *Campylobacter* and *Salmonella* in raw meat products in relation to premises

Premises details	No. samples (n=4340) (%)		Samples with *Salmonella* (%)		Samples with *Campylobacter* (%)	
Premises type						
Licensed butcher	1945	(44.8%)	66	(3.3%)	211	(10.9%)
Supermarket	1674	(38.6%)	51	(3.1%)	185	(11.1%)
Non-licensed butcher	235	(5.4%)	7	(3.0%)	32	(13.6%)
Public house	94	(2.2%)	3	(3.2%)	6	(6.4%)
Restaurant	105	(2.4%)	3	(2.6%)	8	(7.6%)
Market stall	106	(2.4%)	1	(1.0%)	12	(11.3%)
Wholesaler	40	(0.9%)	0		2	(5.0%)
Farm shop	58	(1.4%)	0		1	(1.7%)
Café	14	(0.3%)	0		2	(14.3%)
Hospital	7	(0.2%)	0		0	
Greengrocer	9	(0.2%)	0		0	
Other (convenience store, hotel, take-away, prison kitchen, port of entry)	52	(1.2%)	1	(1.9%)	1	(1.9%)
Not recorded	1	(<1%)	0		0	
Display/Storage temperature of raw meat						
Equal/below 8°C	4015	(92.5%)	125	(3.1%)	427	(10.6%)
Above 8°C	191	(4.4%)	5	(2.6%)	19	(10.0%)
Not Recorded	134	(3.1%)	2	(1.5%)	14	(10.5%)
Open raw meat & RTE* food handled on premises						
Yes	2902	(66.9%)	101	(3.5%)	298	(10.3%)
No	1166	(26.9%)	23	(2.0%)	129	(11.1%)
Not recorded	272	(6.2%)	8	(2.9%)	33	(12.1%)

*RTE, ready-to-eat

The majority (92.5%) of samples were displayed or stored at equal/below 8°C (Table 10). There was no significant difference in the incidence of *Campylobacter* or *Salmonella* detected between raw meats that were displayed or stored at equal/below or above 8°C (Table 10) (p=1.0000, p=0.9041, respectively).

Two-thirds (66.9%) of samples were collected from premises that handled both open or unwrapped raw meat and ready-to-eat food (Table 10). Most (92.6%) of these samples were from premises that had satisfactory arrangements to prevent cross-contamination between raw meat and ready-to-eat food, however 4.1% did not and for 3.3% of samples, this information was not recorded. Areas of concern identified by the sampling officer at the time of the visit where arrangements were not satisfactory to prevent cross-contamination included handwashing, storage, and other practices such as cleaning procedures and use of chopping boards. A higher proportion of samples containing *Salmonella* (3.5%) were from premises handling both open raw meat and ready-to-eat foods compared to those that did not (2.0%) (p=0.0389) (Table 10).

Discussion

Although much attention has focused on poultry meat[22], red meat also remains a significant cause of foodborne general outbreaks of infectious intestinal disease in the UK. Smerdon *et al*.[6] reported that 16% of the general outbreaks reported to the Health Protection Agency Centre for Infections between 1992 and 1999 were linked

to the consumption of red meat. Beef (34%) and pork (32%) were implicated most frequently, with lamb also implicated in 11% of red meat outbreaks. Contaminated raw or undercooked poultry and red meats are therefore particularly important in transmitting foodborne pathogens such as *Campylobacter* and *Salmonella*. Meat and poultry as a result play a key role in the Food Standards Agency foodborne disease strategy to reduce food poisoning further by 2010[23].

Salmonella spp. and *Campylobacter* spp. have long been associated with raw poultry and the prevalence of these pathogens in raw chicken is well documented compared to other meats. Red meat types were therefore sampled (91%) in this two year study in preference to poultry (9%). Results from the study showed that the prevalence of *Campylobacter* is higher than *Salmonella* in raw meats and poultry, as has been reported in other studies[4,24-29] Furthermore, raw poultry (all types) was more frequently contaminated with *Campylobacter* (range of 27.4% - 51.7%) compared to that found in red meat types (range of 4.9% - 12.6%). Raw poultry (all types) was also more frequently contaminated with *Salmonella* (range of 5.8% -22.8%) compared to that found in red meats (range of 1.3% - 3.9%).

Of the red meat samples, lamb exhibited the highest contamination from *Campylobacter* (12.6%), followed by pork (6.3%) and beef (4.9%). A similar prevalence of 11.8% in lamb has also been reported in Ireland[30]. Raw lamb/mutton from halal butcher shops in England has also been found to have a high frequency of *Campylobacter* contamination (23%)[28]. In contrast, Wong *et al.*[31] reported a much lower prevalence of *Campylobacter* of 6.9% in lamb and mutton in New Zealand. Reported rates of *Campylobacter* contamination of pork meat vary from 1.6% to 10.3%[26,27,30-32]. The prevalence of *Campylobacter* in beef is also generally low; previous studies demonstrated that this pathogen was isolated from only 0.5% to 3.5% of the beef samples tested[26,27,30-33].

With regard to the prevalence of *Salmonella* in red meats, pork exhibited the highest contamination from *Salmonella* (3.9%) in this study, followed by lamb (2.0%) and beef (1.3%). Other studies in the US and Italy also found the rate of *Salmonella* contamination to be higher in pork (3.3% - 9.9%%) compared to beef products (1.0% - 1.9%)[26,34]. The carriage rate of *Salmonella* in pigs at slaughter in Great Britain during 2003 has been reported to be much higher (23.4%) than that found in cattle (1.4%) and sheep (1.1%)[2]. The most common serotypes from cattle at slaughter were *S*. Typhimurium (28%), *S*. Mbandaka (28%) and *S*. Dublin (22%), in pigs *S*. Typhimurium (54%) and *S*. Derby (25%), and in sheep *S*. Dublin (13%). *S*. Typhimurium was also the most common serotype isolated from raw beef and pork samples in this study, and also in lamb samples. The other common serotypes obtained from animal species at slaughter were also recovered from beef, pork and lamb samples in this study with the exception that *S*. Dublin was not recovered from any lamb samples.

Contamination of raw meat with pathogens has been shown to occur during slaughter and evisceration. The microbial status of offal, such as livers, of food animals is an indicator of slaughterhouse hygiene practices[3]. In the present study *Campylobacter* and *Salmonella* were found in 25.6% (89/348) and 11.2% (39/348) of offal samples respectively, but the incidence in different meat types of offal varied. *Campylobacter* were most frequently isolated from lamb offal (36.6%), followed by pig (17.5%), chicken (14.2%), and beef (12.2%) offal. However, *Salmonella* were most frequently isolated from pig offal (23.6%), and less so from beef (6.1%) and lamb (3.1%) offal. These differences possibly reflect the level of intestinal carriage of *Campylobacter* and *Salmonella* in these animals[2,35]. Raw lambs', pigs' and ox livers have also been shown by Kramer *et al.*[3] to be frequently contaminated with *Campylobacter* (54% to 73%).

Although raw poultry was sampled in relatively low numbers, overall *Salmonella* was detected from 5.8% of fresh chicken in the present study and is similar to that found in the FSA survey carried out in the UK during 2001 (4%)[4]. Other recent surveys of fresh poultry in the UK and elsewhere have shown variable *Salmonella* contamination rates ranging from 1.5% to 60%[24-26,29,34,36-40]. Whilst the prevalence of *Salmonella* in fresh raw chicken was found to be low in the present study, a higher incidence of *Campylobacter* was found in samples (51.7%) and is similar to that reported in the FSA survey (56%)[4]. Of the poultry meat samples, chicken exhibited the highest contamination from *Campylobacter* (51.7%), followed by game bird meat (41.8%; mostly duck) and turkey (27.4%). In comparison, game bird meat (mostly duck) had the highest contamination by *Salmonella* (22.8%) compared to other poultry types (5.8-6.8%). The high rate of contamination of raw duck with both *Salmonella* and *Campylobacter* highlights an issue which may need to be considered further in terms of any precautions or advice for the safe preparation, cooking and service of such meats. Similar *Campylobacter* prevalence rates were reported in poultrymeat sampled in Ireland[30]. However, other studies in the UK and elsewhere indicate that the frequency of campylobacter contamination is also variable, ranging from 29-94%[24-27,29,30,32,33,36,40-41]. Such variations in *Salmonella* and *Campylobacter* contamination may have resulted partly from differences in methodology, country of origin, seasonality, and poultry production and processing methods.

Of the campylobacters recovered from raw meats most were *C. jejuni*, with *C. coli* accounting for much of the remainder. This is in accordance with that previously found in retail raw chicken and offal[3] and also in human isolates in England and Wales[42]. All *C. jejuni* and *C. coli* raw meat isolates were resistant to at least one antimicrobial drug and in general, *C. coli* isolates were more multi-resistant to antimicrobial drugs, including erythromycin and the quinalones such as ciprofloxacin and naladixic acid, than *C. jejuni*. Resistance to ciprofloxacin and erythromycin has also been shown to be higher in human *C. coli* isolates (45% and 39%, respectively) than in *C. jejuni* (29% and 2%, respectively)[14]. The most common serotypes of *C. jejuni* and *C. coli* seen in human isolates in England and Wales during 2000-2002 were HS13 and HS50, and HS56, respectively[42]. The HS13 and HS50 serotypes were also predominant in *C. jejuni* isolates obtained from beef, pork, lamb and chicken samples in this study. *C. coli* HS56 was detected in meat and poultry samples but was not a predominant serotype. Results from the study have also indicated that multiple *Campylobacter* species are present in raw meats (primarily chicken samples), which has also been seen in other studies[3,26]. Furthermore, different HS-serotypes of the same species can also be present in one sample, which presents a challenge to molecular typing methods used for epidemiological or outbreak investigations.

The antimicrobial drug resistance of *Salmonella* isolates differed according to the sero- and phage type of the organism and the meat source of isolation. *S.* Typhimurium isolates displayed significantly higher rates of multiple drug resistance than other serotypes. Among multiple drug resistance isolates, such as serotypes Typhimurium DT104/104b and PT U302, resistance to tetracyclines, sulphonamides, streptomycin, ampicillin, spectinomycin, chloramphenicol and trimethoprim was most often observed. Foodborne transmission of *S*. Typhimurium DT104 has been well documented, and several outbreaks have involved the consumption of contaminated meat[43,44]. The results of this study suggest that antimicrobial resistance in *Salmonella* and *Campylobacter* isolates from raw meats is relatively common and that practice at the farm level may be a contributory factor to the presence of antimicrobial resistance in these foodborne pathogens. However, recent studies have indicated that antimicrobial usage in food production animals in the UK may not be directly related to the occurrence of resistance in certain serotypes, namely *S.* Enteritidis and *S.* Typhimurium, and that other factors should also be considered[45]. Since campylobacteriosis and salmonellosis are transmitted primarily through food, particularly food of animal origin, the presence of antimicrobial drug resistant

Campylobacter and *Salmonella* in raw meats has important public health implications. As part of EU control measures in animals and poultry implemented in 2006, antimicrobials are no longer used except under very limited circumstances, such as animal health and welfare grounds[46,47].

Campylobacter infection has marked seasonality with a sharp rise in human cases in England and Wales occurring in late spring and early summer[42]. It is interesting to note that from this study of raw meats, there appeared to be no obvious seasonal trend in *Campylobacter* prevalence rates in beef, pork or chicken samples, whereas in lamb samples, a peak in prevalence occurred in the autumn months. The incidence of salmonellosis is higher in the summer months. However, no apparent pattern in the seasonality of *Salmonella* prevalence rates in raw meats was observed in this study.

The data from the study carried out from April 2003 to March 2005 indicate that raw meat and poultry were more frequently contaminated with *Campylobacter* and less often with *Salmonella*, and that contamination was dependent on the type of meat. In common with other studies, poultry and offal samples appear to be prominent reservoirs of *Campylobacter* spp. To diminish the presence of *Campylobacter* spp. and *Salmonella* spp. in raw meats, it is critical that risk reduction strategies are used throughout the food chain. These strategies include on-farm practices that reduce pathogen carriage, increased hygiene at both slaughter and meat processing, continued implementation of HACCP principles[48-51], and education of food handlers. The Zoonoses Action Plan (ZAP) *Salmonella* Programme initiated by the British Pig Executive in 2002, and supported by FSA and Defra, aims to reduce the prevalence of *Salmonella* in quality assurance pigs at slaughter by 25%[2]. The FSA target is to reduce *Salmonella* in pigs at slaughter by 50% by 2010[52]. The FSA have also set a target of achieving a 50% reduction in the incidence of UK-produced chickens which test positive for *Campylobacter* by 2010[52]. The EC Regulation on control of salmonella and other specified foodborne zoonotic agents[53] also aims to reduce the occurrence of zoonotic agents at primary production. Pathogen-reducing targets will be set after an investigation on the prevalence of the pathogen in all Member States has been conducted. *Salmonella* has been prioritised for establishing Community targets for the reduction of the prevalence of this organism, particularly in poultry and pigs.

It is also important that consumers apply the basic rules of hygiene to prevent raw meats from contaminating ready-to-eat foods, and ensure that any bacterial pathogens present are destroyed by thorough cooking before the meat is eaten. To this effect, the FSA's foodborne disease strategy[23] is based on a farm-to-fork approach and involves both sector-specific measures[54] and measures that will have impact across all food sectors, including promotion of good hygiene practice to food businesses and consumers[55]. The data presented from the monitoring study of *Campylobacter* and *Salmonella* in raw meats will also contribute to risk assessment and may provide valuable data for investigation of any linkages between raw meat, live animals and cases of human illness on a national basis.

Acknowledgements
The authors would like to thank all the staff in the Environmental Health Departments throughout the UK who collected samples during this study, all the staff in HPA, HPA Collaborating and other Official Food Control Laboratories who performed the microbiological examinations. Thanks are also extended to LEP, HPA Centre for Infections, for typing the S*almonella* and *Campylobacter* isolates, David Lock, LACORS for coordinating the participation of Environmental Health Practitioners and advice from the LACORS Food Examination Focus Group, to the Regional FWE Coordinators Forum for their advice in preparing the sampling protocols, and to Lilian Hucklesby for co-ordinating data entry.

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Annex 1: Participating Laboratories and Local Authority Food Liaison Groups

Table I. Participating HPA and HPA Collaborating Laboratories and number of raw meat samples examined

HPA Region	Laboratory Name	Number Samples
East	Chelmsford	253
	Norwich	296
East Midlands	Leicester	90
	Lincoln	242
London	London Food, Water & Environmental Microbiology	110
North East	Newcastle	146
North West	Carlisle	16
	Chester	203
	Preston	420
South East	Wessex Environmental Microbiological Service	190
	Ashford	156
	Brighton	310
	Reading	29
South West	Bristol	94
	Exeter	57
	Gloucester	34
	Plymouth	18
	Truro	110
West Midlands	Birmingham	34
	Coventry	43
	Hereford	7
	Shrewsbury/Telford	175
	Stoke	116
Yorkshire & Humber	Leeds	112
	Hull	327
	Middlesbrough	117
	Sheffield	264
Total		3969

Table II. Participating laboratories in Wales, Scotland, Northern Ireland & England and number of raw meat samples examined

Country	Laboratory Name	Number Samples
Wales	NPHS-W* Microbiology Cardiff	112
	NPHS-W Microbiology Carmarthen	55
	NPHS-W Microbiology Rhyl	10
Ireland	Belfast City Hospital	145
Scotland	Dundee Scientific Services, Dundee City Council	6
	Analytical & Scientific Services, Edinburgh City Council	16
	Glasgow Scientific Services	10
England	Kings Lynn & West Norfolk	17
Total		371

*; National Public Health Service-Wales

Table III. Participating Food Safety Liaison Groups and number of raw meat samples collected

[#]

Food Liaison Group	Number of Samples
Berkshire	45
Buckinghamshire	6
Cambridgeshire	162
Cheshire	124
Cornwall	110
Cumbria	45
Derbyshire	162
Devon	58
Dorset	70
Durham	56
East Sussex	109
Essex	101
Gloucestershire	34
LFCG[1] Greater London NE Sector	25
LFCG Greater London NW Sector	5
LFCG Greater London SE Sector	13
LFCG Greater London SW Sector	55
Greater Manchester	141
Hampshire & Isle Of Wight	68
Hereford & Worcester	12
Hertfordshire & Bedfordshire	12
Humberside	333
Kent	156
Lancashire	247
Leicestershire	90
Lincolnshire	114
Merseyside	79
North Yorkshire	52
Northamptonshire	24
Northern Ireland[2]	145
Northumberland	36
Norfolk	211
Nottinghamshire	119
Oxfordshire	21
Scottish Food Enforcement Liaison Committee[3]	32
Shropshire	85
Somerset	17
South/West Yorkshire	172
Staffordshire	121
Suffolk	88
Surrey	121
Tees Valley	87
Tyne & Wear	75
Wales North Group	10
Wales South East Group	112
Wales South West Group	82
Warwickshire	10
West Midlands	106
West of England	55
West Sussex	79
Wiltshire	48
Total	**4340**

1, London Food Co-ordinating Group; 2, Northern Ireland Food group comprises of the Eastern, Northern, Southern and Western Groups; 3, SFELG comprises of Central Scotland, Fife & Tayside, Lothian & Scottish Borders, North Scotland, and West of Scotland