Public Health England

FSA Project FS102121

Antimicrobial resistance in Campylobacter jejuni and Campylobacter coli from retail chilled chicken in the UK (Year 2: 2015-16)

Forming part of the project: A Microbiological survey of campylobacter contamination in fresh whole UK produced chilled chickens at retail sale (2015-18)

Frieda Jorgensen, Robert H Madden, Craig Swift, Eve Arnold, Andre Charlett and Nicola C Elviss

ACKNOWLEDGEMENTS

The authors would like to thank:

All staff who were involved in the successful delivery of this project from PHE and AFBI through the sampling and testing of chickens.

Lorna Rowswell, Bettina Mavrommatis and colleagues at the Food Standards Agency (FSA).

Colleagues in Gastrointestinal Bacteria Reference Unit (GBRU) and Statistical Unit at PHE Colindale for speciation and antimicrobial breakpoint testing data.

ABBREVIATIONS

AST	Antimicrobial susceptibility testing
BPW	Buffered Peptone Water
Cp	Ciprofloxacin
cfu	Colony forming units
CI	Confidence Interval
ºC	Degrees Celsius
Ery	Erythromycin
EQA	External Quality Assurance
FSA	Food Standards Agency
g	Gram
GBRU	Gastrointestinal Bacteria Reference Unit
G	Gentamicin
IQA	Internal Quality Assurance
ISO	International Standard Organisation
l	Litre
mCCDA	Modified Charcoal Cefoperazone Deoxycholate Agar
mg	Milligram
MIC	Minimum inhibitory concentration
MRD	Maximum Recovery Diluent
n	Number
Nal	Nalidixic Acid
PHE	Public Health England
SOP	Standard Operating Procedures
spp.	Species
Tet	Tetracycline
S	Streptomycin
UK	United Kingdom
UKAS	United Kingdom Accreditation Service

LIST OF TABLES

LIST OF APPENDICES

EXECUTIVE SUMMARY

This report presents antimicrobial resistance data for isolates collected as part of FSA study FS102121: A microbiological survey of *Campylobacter* contamination in fresh whole UK-produced chilled chickens at retail sale. The isolates were obtained from chicken at retail sale during the period from July 2015 to May 2016.

Campylobacter jejuni and *C. coli* isolates (548) recovered from retail chicken using the EN/TS/ISO 10272-2 standard enumeration method (applied with a detection limit of 10 cfu per gram of skin or per outer packaging swab sample tested) were tested to determine the antimicrobial resistance profiles of the cultures.

Ciprofloxacin resistance was identified in around half of the *C. jejuni* isolates (437) and *C. coli* isolates (108) tested. None of the *C. jejuni* and only 1.9 % of the *C. coli* isolates were resistant to erythromycin and just over three quarters of isolates were resistant to tetracycline. All isolates tested were sensitive to gentamicin. Multidrug resistance defined as reduced susceptibility to at least three antimicrobial classes was found in 1.5 % of all isolates examined. The proportion of multi-resistant isolates was significantly higher within *C. coli* (7.4 %) compared to within *C. jejuni*.

Overall, the proportions of antimicrobial resistant isolates found in this study were similar to that reported in the previous survey year (2014-2015) with erythromycin resistance continuing a decreasing trend. Multi drug resistance (MDR) in *C. coli* was lower compared to that found in the previous survey year. MDR in *C. jejuni* was not detected and thus likely to be very low as reported in the dataset from the first survey year (1 %). However, the data demonstrated significantly higher proportions of ciprofloxacin resistance compared to older data from the 2007/2008 FSA survey and in the CLASSP survey (2010).

It is recommended that trends in antimicrobial resistance in *Campylobacter* isolates from retail chickens continue to be monitored.

1. BACKGROUND

Campylobacter species, especially *Campylobacter jejuni,* are the main cause of human bacterial gastroenteritis in the developed world and it is estimated that there are in excess of half a million cases and 80,000 general practitioner consultations annually in the UK (Strachan et al. 2010, Tam et al. 2011). Source-attribution studies, outbreak investigations and case-control reports all incriminate chicken meat as the key foodborne vehicle for *Campylobacter* spp. infection, with cross-contamination from poultry being identified as an important transmission route (Tam et al. 2009, Danis et al. 2009, Friedman et al. 2004; Mullner et al. 2009, Sheppard et al. 2009). Consumption of undercooked poultry or cross-contamination from raw poultry meat is believed to be an important vehicle of infection (EFSA, 2009). Raw chicken meat is frequently contaminated with *Campylobacter* spp. and a decrease in the exposure levels from this source is likely to reduce the number of human *Campylobacter* cases.

It has been reported that isolates of *C. coli* strains are more likely to exhibit resistance to antimicrobials than *C. jejuni* and it is therefore important to determine trends for *C. coli* and *C. jejuni* as separate species. Antimicrobial resistance in *Campylobacter* spp., especially to fluoroquinolones, has raised concern relating to transfer of resistance in cases impacting on the global increase of resistance seen in infectious organisms. *Campylobacter* spp. isolates from 38 % of cases associated with one UK hospital in 2008 were resistant to ciprofloxacin (Cody et al. 2010). This represented an increase from 2004 where 25 % of isolates were resistant to ciprofloxacin, unlike resistance to erythromycin that had remained at an equivalent level (approximately 2.5 % of isolates). Increased levels of ciprofloxacin resistance have also been reported in the USA (Zhao et al. 2010). It is unclear whether infection with quinolone-resistant *Campylobacter* spp. has adverse clinical consequences, such as prolonged post-infectious complications, and studies published to date have produced conflicting results (Engberg 2004, Evans et al. 2009). In cases where a *Campylobacter* infection warrants treatment with an antibiotic, the drugs of choice are usually macrolides and fluoroquinolones (Skirrow and Blaser 2000). It is therefore important to ascertain any increase in resistance to these groups of antimicrobials in particular.

It is imperative for public health to obtain accurate data on the prevalence of antimicrobial resistant *Campylobacters* in retail chicken as these represent a close point of exposure to consumers. Breakpoint susceptibility testing has been used in a number of previous studies of *Campylobacter* spp. contamination of poultry flocks, carcasses at slaughter and meat samples at retail sale. Integration of antimicrobial resistance data across the food chain will provide a better understanding of how such antimicrobial resistance is emerging and disseminating from animal production to humans.

The European Centre for Disease Prevention and Control (ECDC) and (European Food Safety Authority) EFSA have issued a Technical Document entitled' EU protocol for harmonised monitoring of antimicrobial resistance in human *Salmonella* and *Campylobacter* isolates' (EFSA and ECDC 2016) to provide standardisation of antimicrobial testing methods. Within this document, the panel of antimicrobial for testing *Campylobacter* isolates from animal and food sources includes two antimicrobials, nalidixic acid and streptomycin, which are not included in the protocol for human isolates. The Technical Document states that "*The difference in the*

antimicrobials which are not on both panels is not considered a critical issue as the most important agents are included in both Panels" (EFSA and ECDC 2016).

The interpretation of results from animal and food isolates is based on the Epidemiological cut-off value (ECOFF), which is different from the clinical breakpoint approach for human isolates. EFSA and ECDC recognise this within the Technical Document and state the following:

"*Another difference between the protocols is that clinical breakpoints would primarily be used as the interpretive criteria for human isolates while ECOFFs are used for animal and food isolates. This reflects the difference in the reason for performing antimicrobial sensitivity testing (AST), with treatment of clinical illness being the primary focus for testing in human isolates and early detection of acquired resistance and increased resistance in zoonotic bacteria being the goal for AST in animal and food isolates. Quantitative data can however be reliably compared as the data can then be interpreted with either clinical breakpoints or ECOFFs, depending on the purpose of the analysis. An important consideration in relation to comparison of data is that only dilution susceptibility test data (Minimum Inhibitory Concentration (MIC) expressed in mg/L) are accepted in the monitoring in animals and food. Consideration has been given to adopting an MIC only policy also for human isolates, however the costs of testing all isolates by MIC methods are likely to be prohibitive for many*" (EFSA and ECDC 2016).

It was recognised after the publication of the year one data (FSA project FS241044[1]) that the breakpoints used to determine antimicrobial resistance did not fully agree with the EFSA recommendation for *Campylobacter* species. PHE undertook re-testing of 202 isolates from year 1 to allow comparison of the datasets from the microbiological survey of *Campylobacter* contamination in fresh whole UK-produced chilled chickens at retail sale. Around 10 % of isolates were unable to be recovered from storage after two attempts.

The work presented here aimed to ascertain what proportion of *C. jejuni* and *C. coli* cultures examined were resistant to a range of antimicrobial agents relevant to public health.

[1] https://www.food.gov.uk/science/research/foodborneillness/b14programme/b14projlist/fs241044amr

2. METHODS

The survey protocol agreed with the FSA was used for sampling and *Campylobacter* enumeration testing procedures (FSA 2015).

2.1 Microbiological methods

Campylobacter isolates recovered and confirmed during project FS102121 (A Microbiological survey of campylobacter contamination in fresh whole UK produced chilled chickens at retail sale) were sent to the PHE Gastrointestinal Bacteria Reference Unit (GBRU) for speciation and archiving. A proportion of isolates (funding was available for recovering 600 cultures) were tested for their antimicrobial susceptibility properties by GBRU. Isolates were selected for testing as every tenth isolate (or next viable isolate) but selection was adjusted to ensure adequate representation of producer premises and retailers. If the tenth isolate did not meet the criteria, the 11th, then 12th etc. isolate was reviewed and used to ensure fair representation. A total of 548 isolates were tested including 44 that were recovered during the pilot phase of the FS102121 project running from April to May 2016. All recoverable organic and a high proportion of free range chicken isolates were included.

Muller Hinton Agar with the addition of 5 % horse blood containing specified breakpoint concentrations of antimicrobials were used to determine resistance. Agar quality was monitored using control strains with known minimum inhibitory concentration results. The standard agar break-point testing method was used briefly described as follows: preparation of a suspension of each isolate in sterile saline to McFarland 0.5 turbidity and inoculation onto the surface of each of the antimicrobial containing agars. An isolate was considered resistant when growth was detected on the agar containing antibiotic but scored sensitive if no growth was observed and the corresponding antimicrobial free plate showed pure growth from the suspension applied. Antimicrobial resistance profiles were determined using the epidemiology cut-off (ECOFF) values (Table 2) as recommended in the ECDC EU protocol for harmonised monitoring of antimicrobial resistance in human *Salmonella* and *Campylobacter* isolates (EFSA and ECDC 2016). Multi-resistance was defined in accordance with that used in the 2014 antimicrobial resistance report for the EU (EFSA and ECDC 2016). The main issues when comparing antimicrobial resistance data originating from different datasets are the use of different laboratory methods and different interpretive criteria of resistance. These issues have been addressed by the development of EFSA's guidelines for harmonised reporting of resistance in food-producing animals and food thereof.

The resistance monitoring performed under these guidelines utilises epidemiological cut-off (ECOFF) values which separate the naive, susceptible bacterial populations from isolates that have developed reduced susceptibility to a given antimicrobial agent (Table 1).

The ECOFFs may differ from breakpoints used for clinical purposes, which are defined against a background of clinically relevant data.

Table 1. Antimicrobial groups and the compounds within them

Antimicrobial Group	Antimicrobial(s) included
Aminoglycosides	Gentamicin, Streptomycin
Macrolides	Erythromycin
Quinolones	Ciprofloxacin, Nalidixic acid
Tetracyclines	Tetracycline

The breakpoints used in this report were the ECOFF interpretative thresholds for antimicrobial resistance in *C. jejuni* and *C. coli* (Table 2). Multidrug resistance was defined as reduced susceptibility to at least three antimicrobial classes as specified by the ECDC definition.

Table 2. EUCAST interpretative thresholds for antimicrobial resistance in *C. jejuni* and *C. coli*

Antimicrobial	Species	ECOFF threshold (mg/l)
Erythromycin (Ery)	*C. jejuni*	> 4
	C. coli	> 8
Ciprofloxacin (Cp)	*C. jejuni*	> 0.5
	C. coli	> 0.5
Tetracycline (Tet)	*C. jejuni*	> 1
	C. coli	> 2
Gentamicin (G)	*C. jejuni*	> 2
	C. coli	> 2
Nalidixic acid (Nal)	*C. jejuni*	> 16
	C. coli	> 16
Streptomycin (S)	*C. jejuni*	> 4
	C. coli	> 4

The range of antimicrobials and breakpoints that were used to examine the isolates obtained from the previous FSA survey year (PHE 2016) was slightly different to that used in this study. In the previous report cultures were also tested for resistance to chloramphenicol, kanamycin and neomycin. Furthermore, resistance plates at 1 and 5 mg ciprofloxacin/l, 16 mg erythromycin/l, 1 and 4 mg gentamicin/l, 32 mg nalidixic acid/l, 8 and 128 mg tetracycline and 2 mg streptomycin/l were omitted in this study. The rationale for this amended testing panel was to align with the standard ECOFF thresholds as recommended by EFSA and ECDC.

2.3 Quality Assurance

All laboratories participate in recognised External Quality Assurance schemes, including the FSA funded scheme for enumeration of *Campylobacter* species, as well as operating comprehensive internal quality assurance schemes as part of the requirements of their accreditation to ISO 17025/2005 as assessed annually by the United Kingdom Accreditation Service (UKAS). All analyses were performed by trained and competent staff in a UKAS accredited laboratory operating an appropriate quality management system.

3. RESULTS

All results other than those pertaining to antimicrobial resistance were published in the first and second project reports (PHE 2015, FSA 2015). The antimicrobial susceptibility testing results are presented in detail in Appendix I. The isolates collected from the second year of the survey (year two) were collected from July 2015 to May 2016.

3.1 Antimicrobial resistance in *C. jejuni* and *C. coli* from survey year two

A total of 437 *C. jejuni*, 108 *C. coli* and 3 mixed *C. jejuni/C. coli* isolations from 547 samples were tested for antimicrobial resistance (two separate *C. jejuni* and *C. coli* cultures from one sample, were tested). The isolations tested designated with a "mixed *C. jejuni*/*C. coli*" speciation result related to mixed genotypes or inseparable isolates.

Around half of the *C. jejuni* (54.2 %; n=237/437) and *C. coli* (48.1 %; n=52/108) isolates examined were resistant to ciprofloxacin (Cp) but none of the *C. jejuni* and only 2 (1.9 %) of the *C. coli* isolates were resistant to erythromycin (Ery) (Table 3a). Just over three quarters of all cultures were resistant to tetracycline but all isolates tested were sensitive to gentamicin. Resistance to ciprofloxacin (Cp), nalidixic acid (Nal) and tetracycline (Tet) was detected in two of the mixed *C. jejuni/C. coli* isolations and the remaining one of these was sensitive to all antimicrobials tested.

Table 3a. Antimicrobial resistance in *C. jejuni* and *C. coli* (n = 548) isolated from retail chickens from 2015 – 2016.

Antimicrobial	**No. of resistant isolates (% of isolates resistant) [95 % confidence intervals]**		
	***C. jejuni*[a]** (n = 437)	***C. coli*[b]** (n = 108)	**Total** (n = 548*)
Ery	0 [0 to 0.8]	2 (1.9) [0.2 to 6.5]	2 (0.4) [0.04 to 13.1]
Cp	237 (54.2) [49.4 to 59.0]	52 (48.2) [38.4 to 58.0]	291 (53.1) [48.8 to 57.3]
Tet	296 (67.7) [63.1 to 72.1]	72 (66.7) [56.9 to 75.4]	370 (67.5) [63.4 to 71.4]
G	0 [0 to 0.8]	0 [0 to 3.4]	0 [0 to 0.67]
Nal	244 (55.8) [51.0 to 60.6]	54 (50.0) [40.2 to 59.8]	300 (54.7) [50.5 to 59.0]
S	0 [0 to 0.8]	8 (7.4) [3.3 to 14.1]	8 (1.5) [0.63 to 2.86]
Any Antibiotics	**325 (74.4) [70.0 to 78.4]**	**82 (75.9) [66.7 to 83.6]**	**409 (74.6) [70.8 to 78.2]**

*Including 3 "mixed *C. jejuni/C. coli*" isolates which are not included in either the *C.jejuni* or the *C.coli* columns.

Multidrug resistance defined as reduced susceptibility to at least three antimicrobial classes (according to the ECDC definition[2]) was found in 7.4 % of *C. coli*, but not in any of the *C. jejuni* isolates examined.

The proportion of multi-resistant isolates was significantly higher within *C. coli* compared to within *C. jejuni* ($p < 0.001$; Fishers exact test). In total 139 were fully sensitive with 112 (26 %) *C. jejuni* isolates and 25 (24 %) *C. coli* isolates susceptible to all antimicrobials tested

[2]ECDC definition of MDR for *Campylobacters* taken from EFSA and ECDC 2016

Table 3b. Multi-drug resistance profiles in *C. jejuni* and *C. coli* isolates from retail chickens examined from 2015 – 2016.

Antimicrobial resistance (AMR) profile	No. of isolates with the given AMR profile (% of all isolates with the given profile)		
	C. jejuni (n = 437)	***C. coli*** (n = 108)	**All isolates** (n = 548*)
Tet, Nal, S	0	1 (0.9)	1 (0.2)
Tet, Nal, Cip, S	0	6 (5.6)	6 (1.1)
Tet, Nal, Cip, Ery	0	0	0
Tet, Nal, Cip, Ery, S	0	1 (0.9)	1 (0.2)
Total number	0	8 (7.4)	8 (1.5)

*Including 3 mixed *C. jejuni/C. coli* isolations not included in the other columns.

Table 3c. Antimicrobial resistance associated with *C. jejuni* and *C. coli* in relation to chicken type (isolates from retail chickens from 2015 – 2016)

Antimicrobial	**Chicken type**					
	Standard (n = 454)		**Free-range (n = 76)**		**Organic (n = 18)**	
	C. jejuni (n = 376)	*C. coli* (n = 75)	*C. jejuni* (n = 49)	*C. coli* (n = 26)	*C. jejuni* (n = 11)	*C. coli* (n = 7)
	No. of resistant isolates (Percentage of isolates resistant)					
Ery	0	2 (2.7)	0	0	0	0
Cp	210 (56)	36 (48)	22 (45)	13 (50)	5 (45)	3 (43)
Tet	258 (69)	51 (69)	32 (65)	17 (65)	6 (55)	3 (43)
Nal	215 (57)	38 (51)	23 (47)	13 (50)	6 (55)	3 (43)
S	0	5 (7)	0	3 (12)	0	0
Any antibiotics	278 (74)	56 (75)	38 (78)	21 (81)	9 (82)	5 (71)

*According to ECOFF threshold as described in section 2.1

Differences in levels of ciprofloxacin and tetracycline antimicrobial resistance in strains between standard and organic birds were examined. No significant differences were found (Fishers exact test); however the small sample size, especially for organic chickens, may have limited the ability to detect important differences where they exist.

3.2 Re-testing of isolates from the previous survey year with amended panel used in this study.

Isolates (n = 202) from the first survey year were re-examined using the new EFSA compliant antimicrobial resistance testing panel as described in section 2.1 for the year two isolates.

Comparison of the resistance profile demonstrated excellent agreement between the resistance levels obtained using the original panel and the amended one used for the

year two isolates (Appendix II). Application of the stricter breakpoint for erythromycin resistance (i.e. 8 mg erythromycin/l) for *C. coli* resulted in designating 4 of the original 6 isolates as resistant (reducing erythromycin resistance from 11 to 7.5 %) but all other proportions of resistance to individual antimicrobials remained the same. The proportion of MDR *C. coli* in the dataset from the previous survey year was 17 % (9/53) when applying the stricter breakpoints of 4 mg streptomycin/l and 8 mg erythromycin/l. The proportion of *C. jejuni* designated as MDR remained as with the previous the panel (2/230).

4. Discussion

In agreement with recent EFSA data, resistance to (fluoro)quinolones (ciprofloxacin and nalidixic acid) and tetracycline was most common. Resistance to erythromycin and gentamicin was much rarer in the *Campylobacter* isolates examined. Although the proportions of tetracycline and ciprofloxacin resistant isolates were broadly similar to that reported by EFSA our data showed a slightly higher proportion of tetracycline resistant *C. jejuni* isolates and slightly lower proportion of ciprofloxacin resistant *C. coli* compared to the EFSA data (Table 4a). We found a low proportion of erythromycin resistant *C. coli* isolates compared to the 2014 EFSA data. The reason for this is not known but unlikely to reflect method differences as the PHE testing was designed to be compliant with EFSA recommended protocols. A significantly higher proportion of *C. coli* isolates from this survey (7.4 %) were multi-resistant compared the proportion of multi-resistant *C. jejuni* isolates. This was also observed in the EFSA report (EFSA 2015) where 1.5 % of *C. jejuni* and 12.6 % of *C. coli* cultures exhibited multi-resistance. The reason for this is not well understood but may relate to intrinsic factors e.g. differences in micro-membrane structures in the two species

Table 4a. Antimicrobial resistance in *C. jejuni* and *C. coli* isolates from chicken meat.

Anti-microbial	Break point concentration (mg/l)	Species	% of isolates resistant in dataset			
			2014 to 2015 survey	This survey	EU data 2013[d]	EU data 2014[e]
Cp	> 0.5	*C. jejuni*	49[a]	54	53	66
		C. coli	55[a]	48	76	86
Ery	> 4	*C. jejuni*	0.9	0	0.9	1.6
	> 8	*C. coli*	7.5	1.9	11	17
Tet	> 1	*C. jejuni*	63[c]	68	33	36
	> 2	*C. coli*	68	67	58	74

[a]Data for break point of 1mg Cp/l; [c]Data for break point of 2 mg Tet/l; [d]Data taken from EFSA 2015; [e]Data taken from EFSA 2016

This data from *Campylobacter* isolates obtained from retail chickens on sale from July 2015 to May 2016 showed similar results for antimicrobial resistance compared the data from isolates obtained from survey year 1 (covering February 2014 to March 2015). The proportions of *C. jejuni* or *C. coli* that tested resistant to individual antimicrobials found in this study were not significantly different to those found in the previous survey year (PHE 2016; Table 4b). Comparison of erythromycin resistance in *C. coli* isolates from the first and second survey year was enabled by re-assigning 2 of the 6 *C. coli* isolates from the first survey year that tested resistant to 4 but not 8 mg erythromycin/l to sensitive status. The proportions of MDR *C. jejuni* or *C. coli* (7.4 %) found in this study were not significantly different to those found in the previous survey year (0.9 and 17 %, respectively).

Taken together the datasets from the first and second survey year demonstrate significantly higher proportions of ciprofloxacin resistance than was identified in the 2007/2008 FSA retail chicken survey and in the CLASSP survey (2010).

Table 4b. Antimicrobial resistance amongst the *C. jejuni* and *C. coli* isolates (n = 283) recovered from retail chickens in Year 1 (February 2014 – March 2015[3]).

Antimicrobial (mg/l breakpoint applied)	No. of resistant isolates (Percentage of isolates resistant) [95% confidence intervals]	
	***C. jejuni*; n = 230**	***C. coli;*n = 53**
Ery (4)	2 (0.9) [0.1 to 3.1]	6 (11) [4.3 to 23.0]
Cp (1)	113 (49) [42.5 to 55.8]	29 (55) [40.4 to 68.4]
Tet (2)	144 (63) [56.0 to 68.9]	36 (68) [53.7 to 80.1]
Nal (16)	118 (51) [44.6 to 57.9]	29 (55) [40.4 to 68.4]
S (4)	1 (0.4) [0.01 to 2.4]	8 (15) [6.7 to 27.6]

Interestingly, the EU Summary Report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2014, reported that over the 2008–2014 period, statistically significant increasing trends in resistance to ciprofloxacin and erythromycin were observed in several member states for both *C. jejuni* and *C. coli* (EFSA and ECDC 2016). It has been suggested that an increased level of fluoroquinolone resistant bacteria may relate to increased consumption of fluoroquinolones possibly exacerbated by a fitness advantage of resistant strains (Redgrave et al. 2014). Similar levels of ciprofloxacin and erythromycin resistance has been observed in isolates from human cases (Nichols et al. 2012; Cody et al. 2010).

The proportion of erythromycin resistant *C. jejuni* and *C. coli* isolates from UK chicken in this survey was lower compared to that found in the FSA 2007/2008 UK retail chicken survey suggesting a continuing decreasing trend in erythromycin resistance (PHE 2016). It is important to ascertain any changes in erythromycin resistance as resistance to erythromycin is associated with resistance to other macrolides including clarithromycin, which is often used in preference to erythromycin to treat infections.

In summary, the data from the two survey years suggest that the proportion of ciprofloxacin resistant *C. jejuni* and *C. coli* isolates has increased since 2007-2008 while the proportion of erythromycin resistant *C. coli* and *C. jejuni* may be decreasing.

Given the high prevalence of resistance to fluoroquinolones, and the assessment that a large proportion of human campylobacteriosis infections probably relate to handling, preparation and consumption of chicken meat, this raises concern about the availability of effective antimicrobial agents for the treatment of severe human *Campylobacter* infections. Nevertheless, co-resistance to the critically important ciprofloxacin and erythromycin was very low (0.2 %).

It is recommended that trends in antimicrobial resistance in *Campylobacter* isolates from retail chickens continue to be monitored. It would also be useful to examine more isolates from organic birds to enable a more robust comparison with isolates from chicken not reared to organic standards.

[3] Data from PHE 2016

5 REFERENCES

Anonymous. 2006. International Organisation for Standardisation ISO/TS 10272-2. Microbiology of food and animal feeding stuffs – horizontal method for the detection and enumeration of *Campylobacter* – Part 2: colony count technique. International Organisation for Standardisation, Geneva.

CLASSP Project Team 2010. LACORS/HPA Coordinated Local Authority Sentinel Surveillance of Pathogens (CLASSP) Final Report.

Cody AJ, Clarke L, Bowler IC, Dingle KE. 2010. Ciprofloxacin-resistant campylobacteriosis in the UK. Lancet. 376:1987.

Danis, K., Di Renzi, M., O'Neill, W., Smyth, B., McKeown, P., Foley, B., Tohani, V. and Devine, M. 2009. Risk factors for sporadic *Campylobacter* infection: an all-Ireland case-control study. Euro Surveill. 14. pii: 19123.

Engberg, J., Neimann, J., Nielsen, E.M., Aerestrup, F.M. and Fussing, V. 2004. Quinolone-resistant *Campylobacter* infections: risk factors and clinical consequences. Emerg Infect Dis. 10:1056-63.

EFSA (European Food Safety Authority) and ECDC (European Centre for Disease Prevention and Control), 2015. EU Summary Report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2013. EFSA Journal, 13:4036, 178 pp., doi:10.2903/j.efsa.2015.4036

EFSA (European Food Safety Authority) and ECDC (European Centre for Disease Prevention and Control), 2016. The European Union summary report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2014. EFSA Journal, 14:4380, 207 pp. doi:10.2903/j.efsa.2016.4380

EFSA (European Food Safety Authority). 2009. Scienitifc Opinion on Quantification of the risk posed by broiler meat to human campylobacteriosis in the EU (adopted 9 December 2009) http://www.efsa.europa.eu/en/scdocs/scdoc/1437.htm

Evans MR, Northey G, Sarvotham TS, Rigby CJ, Hopkins AL and Thomas DR. 2009. Short-term and medium-term clinical outcomes of quinolone-resistant *Campylobacter* infection. Clin Infect Dis. 48:1500-1506.

Food Standards Agency 2009 FSA report for the UK survey of *Campylobacter* and *Salmonella* contamination of fresh chicken at retail sale. FSA Project B18025. http://tna.europarchive.org/20140306205048/http://multimedia.food.gov.uk/multimedia/pdfs/fsis0409.pdf (Last accessed 28 July 2016)

Food Standards Agency 2015. A UK wide microbiological survey of Campylobacetr contamination in fresh whole chilled chickens at retail sale (Year2/3/4). https://www.food.gov.uk/sites/default/files/Campylobacter%20Retail%20Survey%20Year%202%20protocol%20%28final%29.pdf
(Accessed 22 January 2016)

Public Health England. 2015. A Microbiological survey of *Campylobacter* contamination in fresh whole UK produced chilled chickens at retail sale (2014-15).

https://www.food.gov.uk/sites/default/files/campylobacter-retail-survey-final-report.pdf.

Public Health England. 2016. Antibiotic Resistance Report for FS241044 - Sept 2016 [Forming part of the project: A Microbiological survey of *Campylobacter* contamination in fresh whole UK produced chilled chickens at retail sale (2014-15)]. https://www.food.gov.uk/sites/default/files/phe-report-amr.pdf.
(Accessed 23 January 2017)

Friedman, C.R., Hoekstra, R.M., Samuel, M., Marcus, R., Bender, J., Shiferaw, B., Reddy, S., Ahuja, S.D., Helfrick, D.L., Hardnett, F., Carter, M., Anderson, B. and Tauxe, R.V.; Emerging Infections Program FoodNet Working Group. 2004. Risk factors for sporadic *Campylobacter* infection in the United States: A case-control study in FoodNet sites. Clin Infect Dis. 38 Suppl 3:S285-96.

Mullner, P., Jones, G., Noble, A., Spencer, S.E., Hathaway, S. and French, N.P. 2009. Source Attribution of Food-borne Zoonoses in New Zealand; a modified Hald Model. Risk Anal. 29:970-984.

Redgrave, L. S., S.B. Sutton, M.A. Webber, and L.J.V. Piddock 2014 Fluoroquinolone resistance: mechanisms, impact on bacteria, and role in evolutionary success. Trends in Microbiology, 22:438-445.

Sheppard SK, Dallas JF, Strachan NJC, MacRae M, McCarthy ND, Wilson DJ, Gormley FJ, Falush D, Ogden ID, Maiden MCJ and KJ Forbes 2009. *Campylobacter* genotyping to determine the source of human infection. Clinical Infectious Diseases 48:1072-1078.

Skirrow, M.B. and Blaser, M.J. 2000. Clinical aspects of *Campylobacter* infection. In Campylobacter, 2nd edn ed. Nachamkin, I. and Blaser, M.J. pp. 69–88. Washington, D.C: ASM Press.

Strachan NJC, Forbes KJ. 2010. The growing UK epidemic of human campylobacteriosis. Lancet , 376: 665–67.

Tam CC, Rodrigues LC, Viviani L, Dodds JP, Evans MR, Hunter PR, Gray JJ, Letley LH, Rait G, Tompkins DS and O'Brien SJ 2011. Longitudinal study of infectious intestinal disease in the UK (IID2 study): incidence in the community and presenting to general practice. Gut. 61:69-77

Tam, C.C., Higgins, C.D., Neal, K.R., Rodrigues, L.C., Millership, S.E., O'Brien, S.J. 2009. Campylobacter Case Control Study Group. Emerg. Infect. Dis. 15:1402

Zhao S, Young SR, Tong E, Abbott JW, Womack N, Friedman SL and PF McDermott. 2010. Antimicrobial resistance of *Campylobacter* isolates from retail meat in the United States between 2002 and 2007. Appl Environ Microbiol. 76:7949-56.