Public Health England

FSA Project FS102121

Antimicrobial resistance in Campylobacter jejuni and Campylobacter coli from retail chilled chicken in the UK (Year 4: 2017-18)

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, Nicolae Corcionivoschi, Craig Swift, Martin Day, Andre Charlett and Nicola C Elviss

Acknowledgements

The authors would like to thank:

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

Abrar Jaffer, Tara French, Kirsten Stone and colleagues at the Food Standards Agency.

Colleagues in GBRU at PHE Colindale for speciation and AMR data.

Colleagues in PHE Statistics Unit.

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
MS	EU Member States
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
WHO	World Health Organisation

Executive summary

This report presents antimicrobial susceptibility test data for isolates collected as part of the Food Standards Agency study FS102121: A microbiological survey of *Campylobacter* contamination in fresh whole UK-produced chilled chickens at retail sale. This survey began in July 2015 and has enumerated campylobacters in skin samples from whole fresh chickens at retail sale. The isolates in this report were obtained from chicken on sale during the period from August 2017 to July 2018 representing the fourth year of this survey.

Campylobacter jejuni and *Campylobacter coli* isolates (n = 393) were recovered from chicken skin samples using the EN/TS/ISO 10272-2 standard enumeration method (applied with a detection limit of 10 cfu per gram of skin) and were tested to determine the antimicrobial resistance profiles of the cultures. Antimicrobial resistance was assessed using epidemiological cut-off (ECOFF) values.

Ciprofloxacin resistance was identified in 52% of the *C. jejuni* isolates (171/328) and just under half (48%) of the *C. coli* isolates (31/65) tested. Two of the *C. jejuni* (1%) and two of the *C. coli* (3%) isolates were resistant to erythromycin and 52% of *C. jejuni* (171/328) and 60% of *C. coli* isolates (39/65) to tetracycline. None of the *C. jejuni* or *C. coli* isolates tested were resistant to gentamicin whereas 2% of *C. jejuni* (5/328) and 9% of *C. coli* (6/65) were resistant to streptomycin. Multidrug resistance (MDR), defined as reduced susceptibility to at least three unrelated antimicrobial classes, were found in 6 out of 65 *C. coli* isolates (9%) and 5 out of 328 *C. jejuni* isolates (2%).

Overall, the proportions of antimicrobial-resistant isolates found in this study were similar to that reported in the previous survey year (August 2016 to July 2017). Multi-drug resistance was also similar to that found in the previous survey years. The percentages of fluoroquinolone-resistant isolates were similar to that found in the previous survey years but higher compared to data from earlier studies (2007/2008 FSA survey and the Coordinated Local Authority Sentinel Surveillance of Pathogens (CLASSP) survey data from 2004-2006). This finding must be treated with caution, as it could relate to bias in the sample of isolates studied and/or differences in methodology.

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

1. Background

Campylobacter species (spp.), 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 *C. coli* are more likely to exhibit resistance to antimicrobials than *C. jejuni* isolates and it is therefore important to determine trends for *C. coli* and *C. jejuni* as separate species (EFSA and ECDC, 2016). Antimicrobial resistance (AMR) 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 fluoroquinolone-resistant *Campylobacter* spp. has adverse clinical consequences, such as prolonged post-infection complications, and studies published to date have produced conflicting results (Engberg, 2004; Evans *et al*., 2009). In cases where a *Campylobacter* spp. infection warrants treatment with an antimicrobial, the drugs of choice are usually macrolides and fluoroquinolones (Skirrow and Blaser, 2000). It is therefore, particularly important to ascertain any change in resistance to these groups of antimicrobials.

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 the European Food Safety Authority (EFSA) have jointly 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 susceptibility testing methods. Within this document, the panel of antimicrobials for testing *Campylobacter* spp. 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).

The work presented here aimed to ascertain what proportion of the *C. jejuni* and *C. coli* isolates from fresh whole retail chicken examined between August 2017 and July 2018 exhibited resistance to a range of antimicrobial agents relevant to public health. Resistance to streptomycin was included to allow a comparison to be made with the percentage of streptomycin-resistant isolates found in previous survey years.

2. Methods

The survey protocol agreed with the FSA was used for sampling and *Campylobacter* spp. enumeration testing procedures (FSA, 2016).

2.1 Microbiological methods

Campylobacter spp. 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 (recovery of ~ 500 cultures was attempted) were tested for their antimicrobial susceptibility properties. Isolates were selected for testing as every tenth isolate (or next viable isolate) but selection was adjusted to ensure representation of producer premises and retailers as deduced from market share data (source: FSA provided Kantar Market share data 2015). 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 393 isolates were tested. All recoverable isolates (i.e. able to grow after frozen storage) from organic and a high proportion of isolates from free range chicken 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 the antimicrobial, 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 ECOFF values (Table 2) as recommended in the ECDC and EFSA protocol for harmonised monitoring of antimicrobial resistance in human *Salmonella* and *Campylobacter* isolates (EFSA and ECDC, 2016). Multidrug resistance (MDR) 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 ECOFF values which separate the naive, susceptible bacterial populations from isolates that have developed reduced susceptibility to a given antimicrobial agent (Table 1).

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

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

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

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	> 2
	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 was consistent 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. The UKAS accreditation pertaining to the antimicrobial susceptibility testing was according to the ISO 1518:2012 standard.

3. Results

All results other than those pertaining to AMR have been submitted in the fourth survey year report to the FSA for peer-review. The AST results are presented in detail in Appendix I. The isolates tested from this fourth year of the survey (survey year 4) were collected from August 2017 to July 2018. Compared to the previous years, a higher proportion of isolates originated from chickens obtained from smaller retailers, as in the fourth survey year sampling from major retailers ceased after the first quarter while testing of chickens obtained from smaller retailers was continued throughout the survey year until July 2018. This was reflected in the isolates that were subjected to AMR testing with 263 isolates from major retailers and 130 from smaller retailers.

3.1 Antimicrobial resistance in *C. jejuni* and *C. coli* from survey year 4

A total of 328 *C. jejuni* and 65 *C. coli* isolates from 392 samples were tested for antimicrobial resistance (two *C. jejuni* isolates with identical AMR results were obtained from the same sample). Testing identified that 52% of the *C. jejuni* and 48% of the *C. coli* isolates examined were resistant to ciprofloxacin but only two *C. jejuni* (1%) and two (3%) of the *C. coli* isolates were resistant to erythromycin (Table 3a and Figure 1). The resistance of the *C. coli* strains to the 4 mg erythromycin per l cut-off was also tested and eight *C. coli* isolates were able to grow at this level (but not at the ECOFF limit of 8 mg/l). Of all the isolates tested, 53% were resistant to tetracycline and 3% to streptomycin, but all isolates tested were sensitive to gentamicin.

Table 3a. Antimicrobial resistance in *C. jejuni* and *C. coli* (n = 393) isolated from retail chickens from 2017 – 2018 (all samples included).

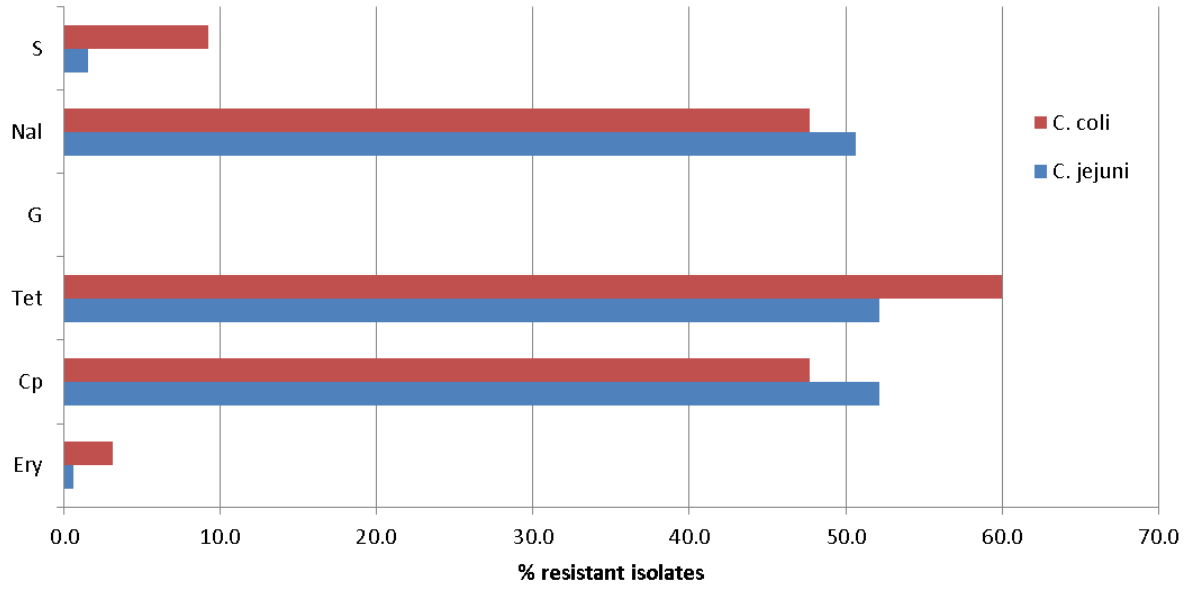
Antimicrobial	No. of resistant isolates		
	(% of isolates resistant; 95% confidence interval)		
	C. jejuni (n = 328)	***C. coli*** (n = 65)	**Total** (n = 393)
Ery	2	2	4
	(1; 0.07-2.2)	(3; 0-11)	(1; 0-3)
Cp	171	31	202
	(52; 47–58)	(48; 35-60)	(51; 46-56)
Tet	171	39	210
	(52; 47–58]	(60.0; 47-72)	(53; 48-58)
G	0	0	0
	(0; 0-1)	(0; 0-6)	(0; 0-1)
Nal	166	31	197
	(51; 45-56)	(48; 35-60)	(50; 45-55)
S	5	6	11
	(1.5; 1-4)	(9; 3-19)	(3; 1-5)
Any tested	215	50	265
	(62; 60-71)	(77; 65-86)	(67; 63-72)

In comparison, antimicrobial resistance profiles for isolates obtained from chickens sold by major retailers only were similar although the proportion of *C. jejuni* isolates with resistance to tetracycline was slightly lower (Table 3b).

Table 3b. Antimicrobial resistance in *C. jejuni* and *C. coli* (n = 263) isolated from retail chickens (sampled from major chains only) from 2017 – 2018.

	No. of resistant isolates (% of isolates resistant)		
Antimicrobial	***C. jejuni*[a]** (n = 232)	***C. coli*[b]** (n = 31)	**Total** (n = 263)
Ery	0	2	2
	(0)	(6)	(1)
Cp	113	17	130
	(49)	(55)	(49)
Tet	104	19	123
	(45)	(61)	(47)
G	0	0	0
	(0)	(0)	(0)
Nal	108	16	124
	(47)	(52)	(47)
S	3	1	4
	(1)	(3)	(2)

Figure 1. Comparison of the percentages of drug-resistant *C. jejuni* or *C. coli* isolates from retail chickens for survey year 2017 - 2018.



Multidrug resistance, defined as reduced susceptibility to at least three unrelated antimicrobial classes (according to the ECDC definition[1]), was found in six *C. coli* (9%) and five *C. jejuni* (2%) isolates examined (Table 4). The proportion of MDR isolates was significantly higher within *C. coli* compared to within *C. jejuni* (p = 0.004; Fishers exact test). In total, 128 were fully sensitive with 113 (34%) *C. jejuni* isolates and 15 (23%) *C. coli* isolates susceptible to all antimicrobials tested.

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

Table 4. Multi-drug resistance profiles in *C. jejuni* and *C. coli* isolates from retail chickens examined in survey 2017 - 2018.

AMR profile	No. of isolates with the given AMR profile (% of isolates; 95% CI)		
	C. jejuni (n = 328)	C. coli (n = 65)	All isolates (n = 393)
Tet, Nal and/or Cip, S	4	4	8
Tet, Nal and/or Cip, Ery	1	2	3
Total for all profiles	5 (2; 1-4)	6 (9; 4-19)	11 (3; 1-5)

Differences in levels of ciprofloxacin- and tetracycline-resistance for isolates from standard and free-range birds were examined (Table 5). There were no differences within *C. jejuni* or *C. coli* isolates from free-range chickens compared to isolates recovered from standard chickens (Table 5). Differences in levels of ciprofloxacin- and tetracycline-resistance in isolates from standard and organic birds were also examined. No significant differences were found; the small sample size for organic and to a lesser extent free-range chickens, may have limited the ability to detect important differences should they exist.

Table 5. Antimicrobial resistance in *C. jejuni* and *C. coli* isolates from retail chickens on sale 2017 – 2018 in relation to chicken type.

Antimicrobial	Chicken type					
	Standard (n = 340)		Free-range (n = 47)		Organic (n = 6)	
	C. jejuni (n = 294)	*C. coli* (n = 46)	C. jejuni (n = 30)	*C. coli* (n = 17)	C. jejuni (n = 4)	C. coli (n = 2)
	No. of resistant isolates (% of isolates; 95% CI)					
Ery	2 (1; 0-2)	2 (4; 1-15)	0 (0; 0-12)	1 (6; 0-29)	0 (0; 0-60)	0 (0; 0-85)
Cp	155 (53; 47-59)	19 (41; 27-57)	15 (50; 31-68)	11 (65; 38-86)	1 (25; 1-81)	1 (50; 1-99)
Tet	160 (54; 49-60)	28 (61; 45-75)	10 (33; 17-53)	10 (59; 33-82)	1 (25; 1-81)	1 50
Nal	152	19	13	11	1	1
	(52; 49-58)	(41; 27-57)	(43; 25-63)	(65; 38-86)	(25; 1-81)	(50; 1-99)
S	5	4	0	2	0	0
	(2; 1-4)	(9; 2-21)	(0; 0-12)	(12; 2-36)	(0; 0-60)	(0; 0-85)

*According to ECOFF threshold as described in section 2.1

The proportion of *C. jejuni* or *C. coli* isolates from standard, free-range and organic chicken that were subjected to antimicrobial testing over the survey years was compared (Table 6). While the proportion of *C. coli* from free range birds was high in the third survey year, no significant differences were found.

Table 6. Comparison of the proportions of *C. jejuni* and *C. coli* isolates from standard, free range or organic retail chickens that were subjected to antimicrobial susceptibility testing in relation to survey year.

	Standard		Free-range		Organic	
Survey year	C. jejuni	C. coli	C. jejuni	C. coli	C. jejuni	C. coli
	% of *C. jejuni* or *C. coli* isolates					
1	86.1	64.2	11.7	24.5	2.2	11.3
2	82.2	69.4	14.5	24.1	3.3	6.5
3	88.5	53.1	9.0	40.6	2.5	6.3
4	89.6	70.8	9.1	26.2	1.2	3.1

4. Discussion

In agreement with recent EFSA data, this study found that quinolone (ciprofloxacin and nalidixic acid) and tetracycline resistance was common in campylobacters isolated from chicken meat (EFSA and ECDC, 2018). In comparison, resistance to erythromycin, streptomycin and gentamicin was much rarer in the *Campylobacter* spp. isolates examined.

Although the proportions of tetracycline and ciprofloxacin-resistant isolates were broadly similar to that reported by EFSA on average for all MS, the survey year data presented in this report found a slightly higher proportion of tetracycline-resistant *C. jejuni* isolates but a lower proportion of ciprofloxacin-resistant *C. coli* compared to the EFSA data (Table 6). This study also found a lower proportion of erythromycin-resistant *C. coli* isolates (3%) compared to the EFSA data (13% in 2016). The reasons for this are not known but are unlikely to reflect method differences as the AST was designed to be compliant with EFSA-recommended protocols using identical cut-off values.

A significantly higher proportion of *C. coli* isolates exhibited MDR compared to the proportion of MDR *C. jejuni* isolates. This was also observed in the previous survey years where 9.4 and 6.7 % of *C. coli* and 1.6 and 1.6 of % *C. jejuni*, were classed as MDR in the 2016-17 and 2015-16 survey years, respectively. EFSA data from 2016 also reported a higher proportion of MDR *C. coli* (1.9%) compared to *C. jejuni* (1.1%) isolates recovered from chickens (EFSA and ECDC, 2018). 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.

This data from *Campylobacter* spp. isolates obtained from retail chickens from August 2016 to July 2017 showed similar results for AMR compared to the data from isolates obtained from the previous survey years (Table 6).

The proportion of tetracycline-resistant *C. jejuni* was, significantly lower in this study compared to that found in the combined data from the first and second survey year (Fishers exact test; $p < 0.001$; Table 6). Otherwise, there was no significant difference in the proportion of drug-resistant *C. jejuni* for any of the other antimicrobials compared to those found in the previous survey year (PHE, 2018). The proportions of MDR *C. jejuni* or *C. coli* found in this study were not significantly different to those found in the previous survey years.

Taken together the datasets from the four survey years demonstrate significantly higher proportions of ciprofloxacin-resistance than found in earlier studies including the 2007/2008 FSA retail chicken survey and in the 2010 CLASSP survey (Figure 2).

This finding must be treated with caution, as the isolates obtained in the earlier surveys were derived using enrichment followed by plating, while direct plating (without prior enrichment) was used in the recent survey years. Nevertheless, the actual plating medium (mCCDA) was the same in all survey years and to our knowledge there is no evidence to suggest that enrichment in the standard Bolton broth would or would not be any less likely to select for ciprofloxacin-resistant campylobacters compared to direct plating.

Table 6. Comparison of occurrence of resistance to selected antimicrobials in *C. jejuni* and *C. coli* isolates from chicken meat between this survey and across EU member states.

			% of isolates resistant in dataset				
			UK retail chicken survey year				
Anti-microbial	Break point (mg/l)	Species	2017-18	2016-17	2015-16	2014 -15	EU data 2016[d]
Cp	> 0.5	C. jejuni	52	41	54	49[a]	65
		C. coli	48	52	48	55[a]	81
Ery	> 4	C. jejuni	0.6	0.4	0 [95%CI = 0-1]	0.9	2.2
	> 8	C. coli	3.1	0 [95%CI = 0-4]	1.9	7.5	13
Tet	> 2	C. jejuni	52	54	68	63[b]	49
		C. coli	60	62	67	68	73

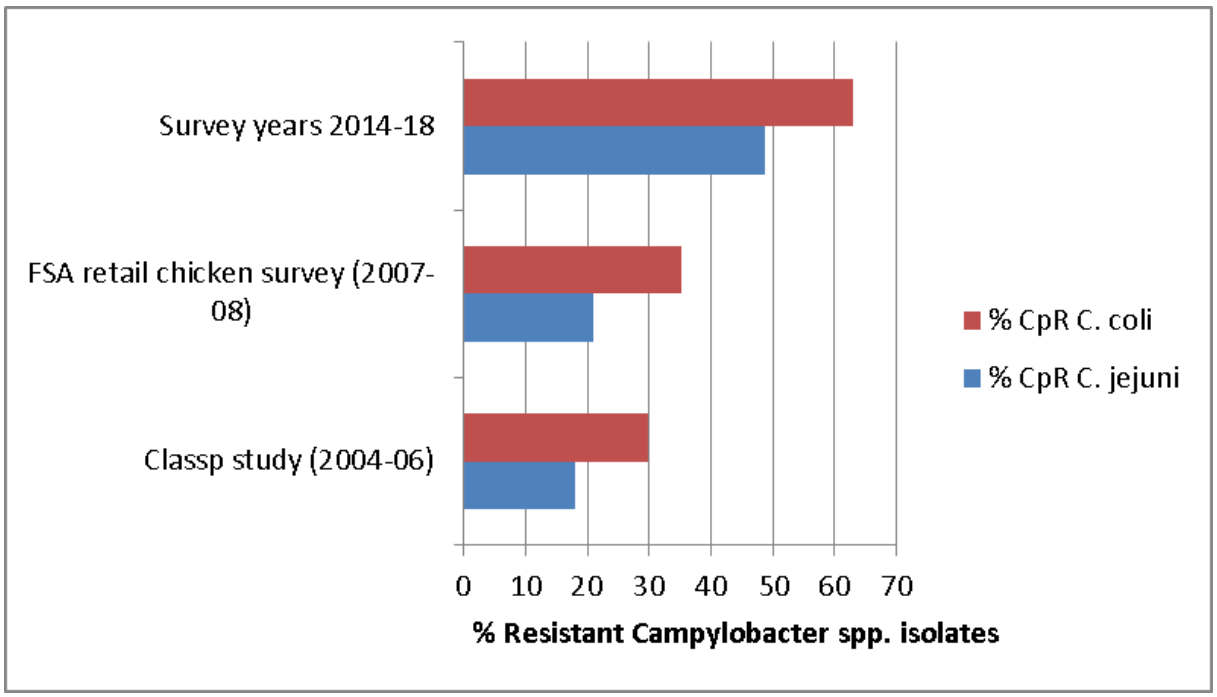
[a]Data for break point of 1 mg Cp/l; [b]Data for break point of 2 mg Tet/l; [c]Data taken from EFSA and ECDC, 2015 (submitted by all MSs); [d]Data (submitted by all MSs) taken from EFSA and ECDC, 2018.

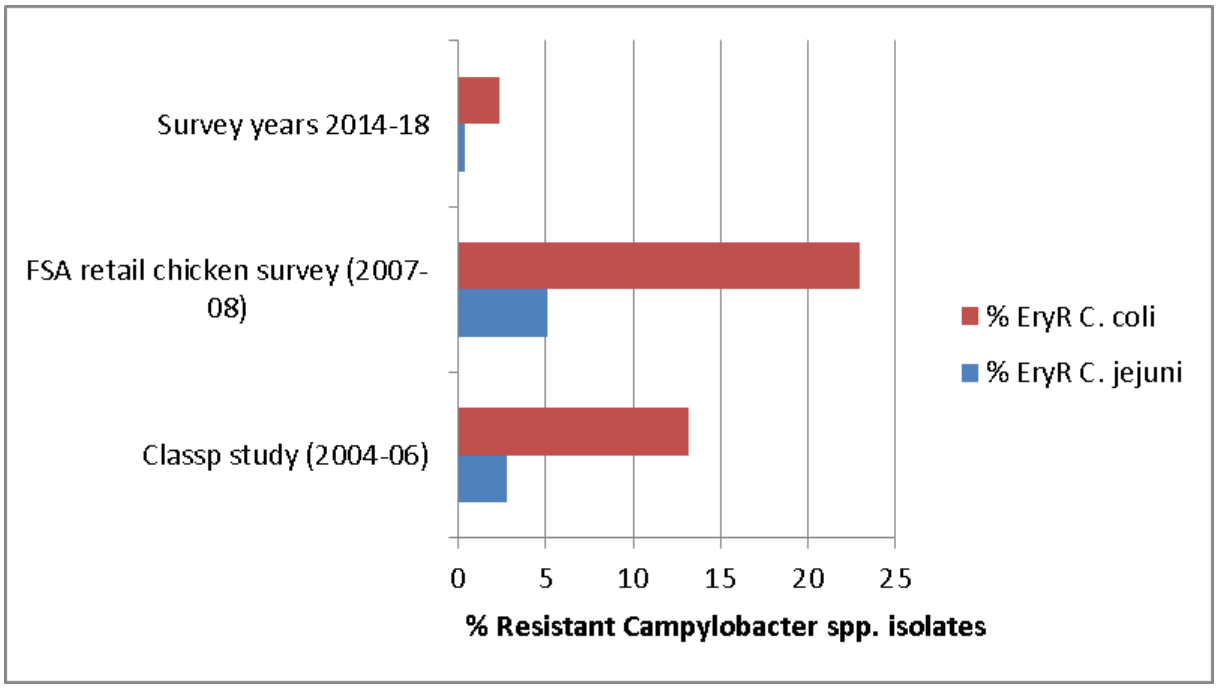
Interestingly, the EU Summary Report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2014, reported that over the 2008 - 2014 period, statistically significant increasing trends in resistance to ciprofloxacin and erythromycin were observed in several MS for both *C. jejuni* and *C. coli* isolates from chicken meats (EFSA and ECDC, 2016). In 2017, the 2nd JIACRA report found that consumption of fluoroquinolones in animals was significantly

associated with increased percentages of resistance to fluoroquinolones in campylobacters from animals and humans (ECDC, EFSA and EMA, 2017). 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 decreasing trend in erythromycin resistance, especially in *C. coli* isolates (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 also used to treat invasive infections.

Figure 2. Comparison of the proportion of ciprofloxacin-resistant (CpR) and erythromycin-resistant (EryR) *C. jejuni* and *C. coli* isolates from survey years 2014 - 2018 with results from prior surveys.





In summary, the average data from all four survey years suggest that the proportion of ciprofloxacin resistant *C. jejuni* and *C. coli* isolates has increased since 2004 - 2008 while the proportion of erythromycin-resistant *C. jejuni* and *C. coli*, maybe decreasing.

Given the high percentage of isolates that are resistant to fluoroquinolones, and the assessment that a large proportion of human campylobacter 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 campylobacter infections. Nevertheless, co-resistance to the critically important antimicrobials ciprofloxacin and erythromycin was very low (0.3% in *C. jejuni* and 3.1% in *C. coli*) (WHO, 2019).

It is recommended that trends in AMR 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 robust comparison with isolates from other chicken production types. This study has shown that fresh retail chicken can be contaminated with campylobacters with reduced antimicrobial susceptibilities and it remains important to ensure hygienic handling and adequate cooking of raw poultry to minimise the possibility of infection (https://www.food.gov.uk/safety-hygiene/campylobacter).

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

Cody AJ, Clarke L, Bowler IC and 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.

ECDC (European Centre for Disease Prevention and Control), EFSA (European

Food Safety Authority), and EMA (European Medicines Agency), 2017. ECDC/EFSA/EMA second joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals – Joint Interagency Antimicrobial Consumption and Resistance Analysis (JIACRA) Report. EFSA Journal;15:4872, doi:10.2903/j.efsa.2017.4872.

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) and ECDC (European Centre for Disease Prevention and Control), 2018. The European Union summary report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2016. EFSA Journal, 16:5182, 270 pp. https://doi.org/10.2903/j.efsa.2018.5182

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). 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, 2016. A UK wide microbiological survey of Campylobacter contamination in fresh whole chilled chickens at retail sale (Year 3/ 4). www.food.gov.uk/sites/default/files/retail_survey_protocol_year3.pdf.

Public Health England, 2015. A Microbiological survey of *Campylobacter* contamination in fresh whole UK produced chilled chickens at retail sale (2014-15). www.food.gov.uk/sites/default/files/campylobacter-retail-survey-final-report.pdf. (Last accessed 22 January 2018).

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)]. www.food.gov.uk/sites/default/files/phe-report-amr.pdf.

Public Health England, 2018. Antimicrobial resistance in *Campylobacter jejuni* and *Campylobacter coli* from retail chilled chicken in the UK (Year 3: 2016-17)

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

www.food.gov.uk/research/research-projects/antimicrobial-resistance-in-campylobacter-jejuni-and-campylobacter-coli-from-retail-chilled-chicken-in-the-uk-0

Friedman CR, Hoekstra RM, Samuel M, Marcus R, Bender J, Shiferaw B, Reddy S, Ahuja SD, Helfrick DL, Hardnett F, Carter M, Anderson B and Tauxe RV; 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 SE, Hathaway S and French NP, 2009. Source Attribution of Food-borne Zoonoses in New Zealand; a modified Hald Model. Risk Anal. 29:970-984.

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 MB and Blaser MJ, 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 and 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 CC, Higgins CD, Neal KR, Rodrigues LC, Millership SE and O'Brien SJ, 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.

World Health Organization (WHO) 2019. Critically important antimicrobials for human medicine, 6th revision. Geneva: World Health Organization.