Public Health England

FSA Project FS102121

Year 4 Report

A microbiological survey of *Campylobacter* contamination in fresh whole UK-produced chilled chickens at retail sale

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Contents

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Abbreviations

ºC	Degrees Celsius
GBRU	Gastrointestinal Bacteria Reference Unit
cfu	Colony forming units
CI	Confidence Interval
EQA	External Quality Assurance
FSA	Food Standards Agency
FSS	Food Standards Scotland
g	Gram
h	Hour(s)
PHE	Public Health England
IQA	Internal Quality Assurance
ISO	International Standard Organisation
l	Litre
LIMS	Laboratory Information Management System
mCCDA	modified Charcoal Cefoperazone Deoxycholate Agar
mg	Milligram
ml	Millilitre
MRD	Maximum Recovery Diluent
n	Number
OR	Odds Ratio
SOP	Standard Operating Procedure
spp.	Species
UK	United Kingdom
UKAS	United Kingdom Accreditation Service

Executive summary

Campylobacter spp. are the most common bacterial cause of foodborne illness in the UK, with chicken considered to be the most important vehicle for this organism. The Food Standards Agency (FSA) agreed with industry to reduce Campylobacter spp. contamination in raw chicken and issued a target to reduce the prevalence of the most contaminated chickens (those with > 1000 cfu per g chicken neck skin) to below 10 % at the end of the slaughter process, initially by 2016.

A UK-wide survey was undertaken to determine the levels of *Campylobacter* spp. on whole UK-produced, fresh chicken at retail sale. The first three survey years of data was collected by FSA Project FS241044 (2014/15)/ FS102121 (2015/2018) and this report represents results from sampling and testing chickens in the fourth survey year. The samples were distributed throughout the UK (in proportion to the population size of each country) and testing was performed by four laboratory sites; three Public Health England (PHE) laboratories and one laboratory in Northern Ireland (Agri-Food & Biosciences Institute, Belfast). *Campylobacter* spp. numeration testing on chicken samples was performed using the EN/TS/ISO 10272-2 standard enumeration method applied with a detection limit of 10 colony forming units (cfu) per gram of neck skin.

During the first months of this 4th survey year chickens (n = 1044) were sampled from all retailer groups, including major retailers, with the large majority (98 %) tested from August to October 2017 (hereafter referred to as the first sampling period). Based on this data, *Campylobacter* spp. were detected in the majority (56 %) of chicken neck skin samples and 7 % of samples had > 1000 cfu per g chicken skin (highly contaminated chicken category). There were significant differences in the proportion of highly contaminated chickens (ranging from 0 to 21 %) between the different types of retailers that could not be explained by differences in remaining shelf-life, chicken weight, sampling period or the type of rearing used. Comparison of individual approval codes (signifying the slaughter house premises) also showed a significant difference in the proportion of chickens with >1000 cfu per g, ranging from 0 to 27 %, and it was noted that some retailers were predominantly supplied by specific approved slaughter premises. There was no significant difference in the proportion of highly contaminated chickens between smaller or larger chickens. There was no evidence of birds with access to range (e.g. free-range and organic birds) being more contaminated than birds reared under standard conditions, but with much fewer free-range and organic birds tested there was limited precision in the comparisons made.

Chickens from smaller retail shops were tested for an entire year, from August 2017 to July 2018 (n = 829). *Campylobacter* spp. were detected in 75 % of these chicken skin samples obtained from non-major retailer shops, and 15 % of samples had counts above 1000 cfu per g chicken skin. Comparison of individual approval codes showed a significant difference in the proportion of chickens with >1000 cfu per g, ranging from 0 to 24 %. The proportion of samples with > 1000 cfu/g of *Campylobacter* spp. was not significantly different over the different sampling periods for these samples collected from an entire year from the smaller retail shops. There was no significant difference in the proportion of highly contaminated chickens between smaller or larger chickens nor was there any evidence that birds with

access to range (e.g. free-range and organic birds) were more contaminated than birds reared under standard conditions.

Taking into account all samples tested during the 4th survey year, *C. jejuni* alone was isolated from the majority (78 %) of chicken skin samples from which isolates were submitted for speciation (n = 1024). *Campylobacter coli* alone was identified in 16 % of samples. Both species were found in 6 % of samples. *C coli* was more frequently isolated from birds with access to range in comparison to those reared as standard birds.

In the samples tested from non-major retail shops, from the entire year (from August to July 2018), *C. jejuni* was slightly less prevalent during the summer period compared to the rest of the year but this difference was not statistically significant.

The average proportion of fresh, whole chicken at retail sale in the UK that are contaminated with a high level of *Campylobacter* spp. has decreased considerably but chickens from the group of shops comprising smaller retailers, independents and butchers remain highly contaminated, suggesting more action is needed to achieve better control of *Campylobacter* spp. in those chickens. Data from this year and the previous survey years have demonstrated an overall substantial decline in the level of highly contaminated fresh, whole UK retail chicken. The FSA has indicated that the retail proxy for the proportion of highly contaminated retail chickens should be less than 7 % and continued monitoring has demonstrated a sustained decline but not for all market sectors.

1.0 Background

Campylobacter species, especially *Campylobacter jejuni (C. 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*. 2012). Source-attribution studies, outbreak investigations and case-control reports all incriminate chicken meat as the key food-borne 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 cases of campylobacteriosis. The packaging of raw chicken has also been identified as a potential risk for infection. However, data published previous to the FSA survey lacked critical information on the levels detected on outer packaging, and it is not known how levels on the outer packaging relate to levels on the chicken it contains (Jorgensen *et al*. 2002).

The Food Standards Agency (FSA) agreed with industry to reduce *Campylobacter* spp. contamination in raw chicken and issued a target for this in order to measure the effectiveness of the FSA's Campylobacter Risk Management Programme (FSA 2010; FSA 2013). The target was to reduce the percentage of chickens produced in UK poultry slaughterhouses (sampled at the post-chill stage) that are contaminated with >1,000 colony forming units (cfu) per gram (g), from a 2008 baseline of 27 % to less than 10 % by December 2015; this target was rolled over to 2016 as it had not been achieved by the end of 2015 (FSA 2015b, FSS 2015).

In theory, such a reduction would also be expected to be reflected in the levels found on chicken at retail sale, although fresh chicken sampled at retail may on average have lower levels of *Campylobacter* spp. compared to those present immediately after slaughter, as *Campylobacter* spp. levels are known to reduce during the shelf-life of the chicken at retail-sale (Purnell *et al*. 2004).

Enumeration

The most important factor known to affect counts of *Campylobacter* spp. on a chicken carcass is the colonisation status of the chicken itself prior to slaughter (EFSA 2010a; Bull *et al*. 2006; Reich *et al*. 2008; Rosenquist *et al*. 2003). Studies have shown that when birds were not colonised at slaughter, *Campylobacter* spp. were either not detected or recorded as being present in very low numbers on carcasses (Allen *et al.* 2007). According to data from an EU survey, a colonised batch of chickens was 30 times more likely to result in a carcass that was contaminated with *Campylobacter* spp. than a non-colonised batch (EFSA 2010b). In the EU survey there was a very high proportion (70 %) of unexplained variance in Campylobacter-contamination results attributable to slaughterhouse-specific factors in colonised broiler batches for countries with a high prevalence, which included the UK. This is supported by other data, that identified different levels of *Campylobacter*

contamination on carcasses despite carcasses originating from the same house and/or batch of birds sent for slaughter (Sampers *et al*. 2008; Figuerosa *et al*. 2009).

The prevalence of *Campylobacter* spp. in retail chicken, as determined by the standard ISO 10272-1 enrichment culture detection (presence/absence) method, has been associated with the time of year sampled (Meldrum 2005, CLASSP Project Team 2010, Hutchison *et al*. 2006). However, the counts in post-chill chickens were not significantly associated with the month of sampling in the 2008 EU survey. The type of sample examined may also affect the counts obtained, but there is evidence that counts from carcass rinse and neck skin samples taken from the same chicken correlate well (Jorgensen *et al*. 2002).

Campylobacter spp. have been enumerated using conventional culture, Enzyme Linked Immunosorbent Assay (ELISA), and methods based on DNA amplification (Jorgensen *et al*. 2002; Borck *et al*. 2002, Oyarzabal *et al*. 2005, Dufrenne *et al*. 2001, Hong *et al*. 2003; Wolffs *et al*. 2005; Fukushima *et al*. 2007). Accurate enumeration data are needed to support effective monitoring and risk assessment of *Campylobacter* spp. contamination in chicken meat and depend on the availability of reliable methods. *Campylobacter* spp. are fastidious bacteria with demanding growth requirements and this may challenge accurate and reliable detection and enumeration (Hutchison *et al*. 2006). While it is normally assumed that detection by enrichment culture is more sensitive than detection by direct plating, the EU survey reported instances where *Campylobacter* spp. were detected by enumeration but not by enrichment suggesting that the enrichment method yielded false negative results (EFSA 2010b). This has been reported elsewhere and may be associated with failure to grow *Campylobacter* sufficiently due to over-growth of other bacteria in the enrichment medium (Habib *et al*. 2008, Jasson *et al*. 2009). The EN/ISO 10272-2 method recommended by the International Organisation for Standardisation provides a horizontal method for the enumeration of *Campylobacter* spp. involving direct plating onto modified charcoal cefoperazone desoxycholate agar (mCCDA) and incubation for 48 h at 41.5 °C (Anonymous, 2017). A collaborative study (Rosenquist *et al*. 2007) confirmed that direct plating on mCCDA is an acceptable protocol for the enumeration of thermotolerant *Campylobacter* spp. in chicken meat. The study, however, also found difficulties in detecting low numbers and variation between laboratories possibly due to difficulties in handling *Campylobacter* spp. Direct spread plating on mCCDA has also been shown to be a reliable alternative to the most probable number method (Scherer *et al*. 2006). This medium was therefore chosen for this study.

In the EU survey about two-thirds of the *Campylobacter* spp. isolates from broiler carcasses were identified as *C. jejuni*, while one third was *Campylobacter coli (C. coli)* (EFSA 2010b). Speciation data is essential for meaningful epidemiological analysis and can allow accurate interpretation of antibiotic resistance data. With the introduction of molecular methods for determining species, these methods have been proven to be quick and reliable using species specific genes (Best *et al*. 2003, Melero *et al*. 2011).

Findings from previous survey years

In March 2012, the FSA put in place a new ongoing UK monitoring programme of chicken carcasses, sampled at post-chill. The FSA also completed a review, with

stakeholders, of the joint campylobacter reduction target that was agreed in 2010, which had incorporated new data (FSA 2013). Industry (with support from the FSA) have developed a programme of initiatives from farm to fork to engage the whole of the food chain regarding the control of *Campylobacter* spp. under the umbrella of the Joint Working Group on Campylobacter (JWG). The JWG then developed into the Acting on Campylobacter Together (ACT) campaign (FSA 2015a). In 2014-15, the FSA funded project FS241044 that looked to gather a year of data from whole raw chicken at retail sale (FSA 2015c). During that first survey year 4,011 samples of whole, UK-produced, fresh chicken from February 2014 to March 2015 were tested. The prevalence of *Campylobacter* spp. in the fresh chicken at retail in the UK was found to be 73.3 % (PHE 2015). A significant proportion (19.4 %) of samples had > 1000 cfu per g chicken skin, and this ranged between all retailers from 12.9 to 29.9 %. Overall, *Campylobacter* spp. were detected from the outer-packaging swab in 6.8 % of samples. The *Campylobacter* spp. contamination found on the outer packaging was at low levels, but between 100 and 4,500 *Campylobacter* spp. cfu per swab were detected in 1.6 % of samples. There were significant differences between retailers that could not be explained by differences in shelf-life remaining, chicken weights, time of year sampled or type of chicken rearing. Some approval codes (signifying the slaughter house premises) also showed a significant difference in the proportion of chickens with >1000 cfu per g, ranging from 9.4 to 29.7 %, and it was noted that some retailers were supplied by specific approved premises. A higher proportion of chickens had a high level of *Campylobacter* spp. during the summer compared to winter months. The larger chickens, those >1750 g in weight, showed a higher risk of being contaminated with >1000 cfu per g. There was no evidence of birds with access to range (e.g. free-range and organic birds) being more contaminated than birds reared under standard conditions but with much fewer free-range and organic birds tested (reflecting market share) no precise comparison could be made. For the majority of chicken skin samples (76.6 %) from which isolates were submitted for speciation, *C. jejuni* was identified. *C. coli* was identified in 13.9 % of samples. Both species were found in 4.2 % of samples. *Campylobacter coli* was more frequently isolated in the summer compared to winter and spring months and was more frequently isolated from birds with access to range. Where *Campylobacter* spp. was isolated from both the skin and the corresponding outer packing sample, the same species was detected in 93 % of these samples. As in the first survey year (project FS241044) it was identified that a significant proportion of chicken on sale in the UK remained contaminated, therefore *Campylobacter* spp. in chicken continued to be important in terms of foodborne disease risk. These findings led to the FSA continuing the monitoring programme over three further years (under project FS102121), aiming to determine the prevalence and levels of *Campylobacter* spp. contamination on fresh whole chilled chickens produced in the UK and sold at UK retail outlets by sampling up to a 36 month period. The project also was to continue to identify *Campylobacter* spp. present and determine susceptibility of isolates to a defined range of antimicrobial agents (the results of antimicrobial susceptibility testing are published as a separate report).

In the second survey year, the prevalence of *Campylobacter* spp. in the fresh chicken at retail in the UK had declined to 61.3 % and the proportion of samples with > 1000 cfu per g chicken skin to 11.4 % (PHE 2017). There were significant differences in the proportion of highly contaminated chickens (ranging from 6.7 to 17.7 %) between retailers that could not be explained by differences in shelf-life

remaining, chicken weights, sampling period or the type of rearing used. Comparing individual approval codes (signifying the slaughter house premises) also showed a significant difference in the proportion of chickens with >1000 cfu per g, ranging from 1.8 to 19.3 %, and it was noted that some retailers were predominantly supplied by specific approved premises. A higher proportion of chickens were highly contaminated with *Campylobacter* spp. during the first summer months compared to the subsequent months. The larger chickens (ie. those weighing > 1750 g) showed a higher risk of being contaminated with >1000 cfu per g. There was no evidence of birds with access to range (e.g. free-range and organic birds) being more contaminated than birds reared under standard conditions but with much fewer free-range and organic birds tested there was limited precision in the comparison made. For the majority of chicken skin samples (83.0 %) from which isolates were submitted for speciation, *C. jejuni* alone was identified. *C. coli* alone was identified in 13.5 % of samples. Both species were found in 3.4 % of samples. *C. coli* was more frequently isolated in the summer months, and also more frequently isolated from birds with access to range.

In the third survey year (4268 samples), the prevalence of *Campylobacter* spp. in the fresh chicken at retail in the UK had declined further to 54 % and the proportion of samples with > 1000 cfu per g chicken skin to 6 % (PHE 2018). There were differences in the proportion of highly contaminated chickens (ranging from 1 to 18 %) between retailer groups and between individual approval codes (ranging from 1 to 19 %). For the majority of chicken skin samples (87.7 %) from which isolates were submitted for speciation *C. jejuni* was identified. *C. coli* was identified in 10.2 % of samples.

In summary, the survey data have shown that the proportion of fresh, whole chicken at retail sale in the UK that are contaminated with a high level of *Campylobacter* spp. has decreased considerably but chickens from the group of shops comprising smaller retailers, independents and butchers have remained more highly contaminated. From July 2017, the top nine retailers agreed to publish their own *Campylobacter* results on their consumer websites and as a result of this, these retailers were no longer included in the survey from 2018. The current focus on smaller establishments and their suppliers may allow the improvements to be made across their supply chain including any supplies into the catering trade.

The purpose of examining numbers of *Campylobacter* spp. in fresh whole chicken on retail sale in the UK for a fourth survey year was to determine whether a sustained decline in contamination remained evident. Furthermore, possible factors affecting the proportion of highly contaminated chickens were investigated using a logistic regression model to enable an assessment of whether associations observed when a variable is assessed in isolation could be explained by confounding.

2.0 Methods

Sampling and testing procedures for the survey and the method evaluation work was agreed with the FSA. The survey protocol used for the time-period from August 2017 to July 2018 is briefly described (FSA 2016; enclosed as Appendix I).

2.1 Sampling method

Sampling was spread across the UK and designed to reflect population sizes. The numbers of free-range and organic chickens sampled within these were based on market share data from Kantar (FSA 2016). During the first months chickens from all retailer groups were tested including major retailers. A similar number of samples were obtained from each major retailer, an approach also used during the second and third survey year (PHE 2017, 2018). Chickens from smaller retail shops were sampled for an entire year, from August 2017 to July 2018. A small number (reflecting a likely very minor market share) of chickens labelled as Halal (including a very few sold by major retailers) or Kosher were also sampled as part of the sample spanning the entire year. Samples for the survey were collected by trained individuals, who purchased samples from retail outlets and transported them to the appropriate testing laboratory according to the survey protocol. On arrival at the laboratory, the air temperature of the cool boxes was taken using calibrated data loggers or temperature probes. Samples were documented using photographs and details were logged onto the laboratory information management system.

2.2 Microbiological methods

Four laboratories undertook the testing during the survey period; three PHE Food, Water and Environmental Microbiology Service Laboratories and the Agri-Food & Biosciences Institute, Belfast. All laboratories enumerated *Campylobacter* spp. based on EN/ISO 10272-2 for the enumeration of *Campylobacter* spp. as detailed in the FSA survey protocol (FSA 2016) using modified Charcoal Cefoperazone Deoxycholate Agar as the primary plating medium.

Neck-skin samples were prepared as described before (Appendix I) using a 1:9 (w/w) dilution of chicken neck-skin and buffered peptone water. Sample weights were between 2 to 10 g pure neck-skin.

2.3 Quality Assurance

During the previous FS241044 project a pilot study of 400 samples was initiated before commencing to establish and validate methods for sampling and enumerating *Campylobacter* spp. in samples from chickens. The pilot provided the basis on which the current survey of whole UK-produced fresh retail chicken was developed. The amended weight of neck skin was validated at the end of survey year 2, from 25 g of neck skin to between 2 and 10 g. This was carried out due to changes in chicken production resulting in increased amounts of neck skin being removed.

All laboratories participate in recognised External Quality Assurance schemes (e.g. https://www.gov.uk/government/collections/external-quality-assessment-eqa-and-proficiency-testing-pt-for-food-water-and-environmental-microbiology) 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 internal audit and review programme.

2.4 Statistical Analysis

Cross tabulations were analysed by the calculation of Clopper-Pearson exact 95 % confidence intervals for the proportion in each cfu per g category. In addition, the Pearson chi square test of association has been used to test the null hypothesis of no association between the measured variable and *Campylobacter* contamination. Fisher's exact test was used for individual comparisons when samples were small. The expected counts in the individual cells of the table, together with the contribution to the overall chi square test statistics have been calculated to enable the identification of specific categories that determine the association.

Logistic regression analysis (a penalised likelihood method (Firth logistic regression) was chosen to cope with zero events) was used to assess whether any associations could be explained as a result of confounding by other important predictors of contamination. The outcome variable used was constructed around the FSA reduction target with the "positive" outcome defined as >1000 cfu per g, and a "negative" outcome being 1000 or fewer cfu per g.

For each predictor variable, the estimated odds ratios prior to and after adjustment for the confounding effects of the other important predictors were obtained from the logistic regression models. This enables an assessment of whether associations observed when a variable is assessed in isolation can be explained by confounding.

Factors examined were retailer, rearing regime, chicken weight, time of test in relation to shelf-life and time period sampled in.

No post-hoc weighting for retailers market share was applied to any of the statistical analyses presented in this report.

3.0 Results

Fresh raw whole UK produced chickens were collected from retail outlets across the UK between August 2017 and July 2018 (Figure 1).

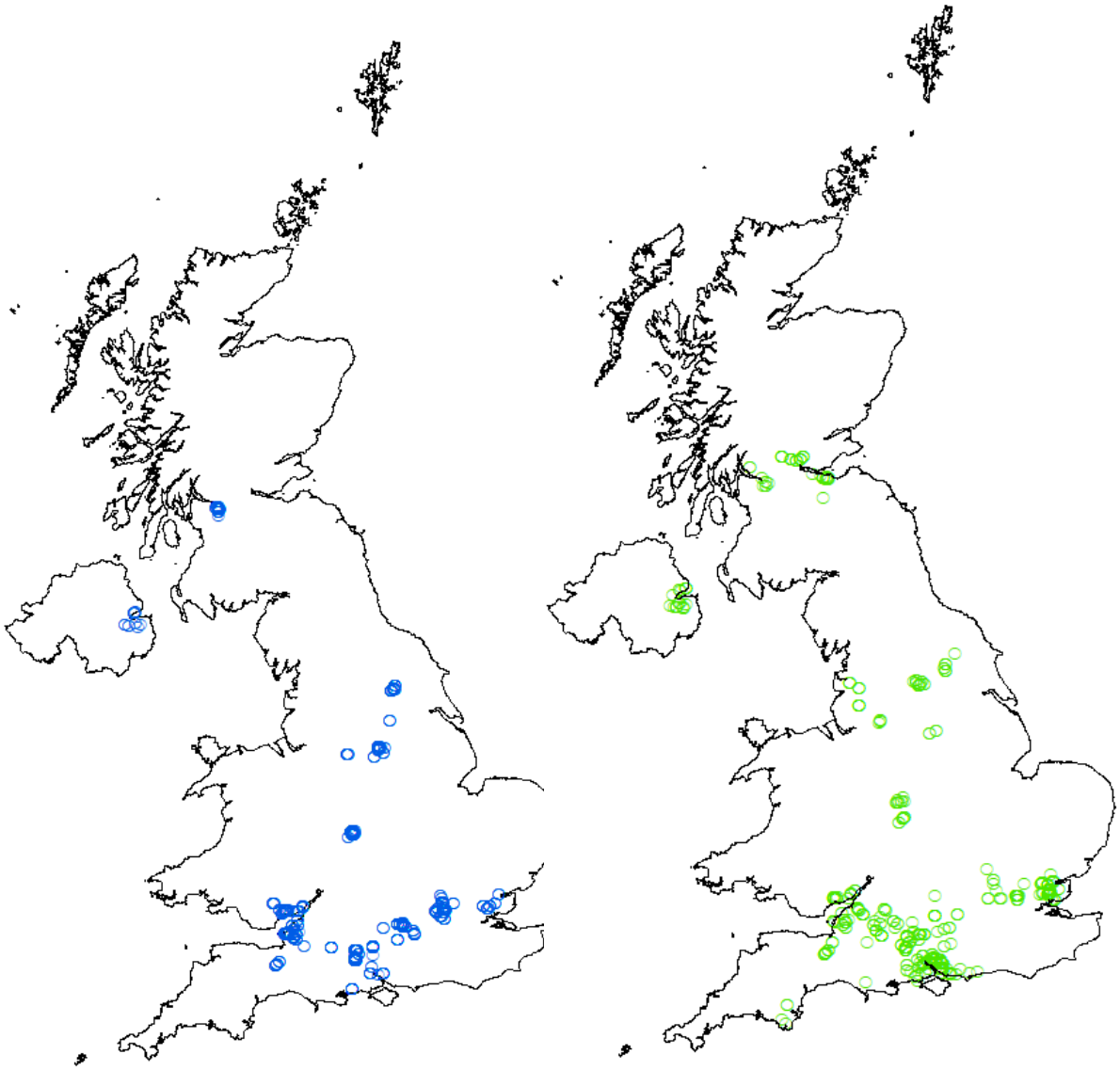

Figure 1a

Figure 1b

Figure 1. Geographical location of chicken samples collected for the survey.

Samples tested as part of the first sampling period that included major retailers (collected from August to October 2017 except for a small proportion collected in early November and December) (Fig1a) and samples tested over an entire year from smaller retail shops (Fig 1b).

Retailers tend to use centralised distribution centres and therefore it is likely that similar chickens are sold in all their stores and because of this and considerations of transport times samples were mainly collected from sentinel urban areas.

Samples from other types of shops including independents and butchers may vary more across the country, nevertheless a wide range of approval numbers were represented and sampled from both northern and southern areas of the country (see section 3.1.3).

3.1 Numbers of *Campylobacter* spp. in chicken skin samples from whole fresh UK produced chicken.

During the first months of this 4th survey year chickens from all types of retail shops were tested from August to October 2017 with an additional small proportion of chickens completed in early November (n = 10) and December (n = 6) to ensure sufficient samples from each of the major retailers (this dataset is hereafter referred to as the first sampling period dataset).

Based on this data, *Campylobacter* spp. were detected in the majority (56 %) of chicken skin samples and 7 % (95 % CI = 5 to 9 %) of the samples had counts above 1000 cfu per g chicken skin. The highest single count detected was 125000 cfu of *Campylobacter* per g chicken skin.

The FSA instructed PHE to continue to test chickens from smaller retail shops only, so that samples from these shops were obtained throughout an entire year, from August 2017 to July 2018 as these chickens were thought to constitute a greater risk. *Campylobacter* spp. were detected in 75 % of these chicken skin samples and 15 % (95 % CI =12 to 17 %) had counts above 1000 cfu per g chicken skin. The highest single count detected was 105000 cfu of *Campylobacter* per g chicken skin.

3.1.1 *Campylobacter* spp. in chicken skin samples in relation to retailer.

The proportion of chickens with *Campylobacter* spp. levels at >1000 cfu per g ranged from 0 to 28 % amongst the retailers tested during the first sampling period (Table 1). Confidence intervals are given for each retailer and these show the likely range of the results allowing for the number of samples taken. The 95 % confidence intervals means that we would expect the true prevalence to fall within the lower and upper confidence limits 95 % of the time.

For the nine larger retailers (i.e. Aldi, Asda, Co-op, Lidl, M&S, Morrisons, Sainsbury's, Tesco and Waitrose) between 0 and 14 % of chicken had *Campylobacter* spp. levels of > 1000 cfu per g. Shops that did not belong to these major retailers (smaller retailers/independent shops) had a significantly ($p < 0.001$; Fishers exact test) higher proportion of chickens with > 1000 cfu per g of *Campylobacter* spp. compared to the average for all samples (Table 1). The proportion of chickens with *Campylobacter* spp. levels at >1000 cfu per g was significantly ($p < 0.01$; Fishers exact test) lower in chickens obtained from Co-op or Waitrose compared to the average for all samples. Similar results and 95 % confidence intervals were obtained when omitting the 20 samples that were taken in November and early December (Appendix III).

Possible confounding of results was investigated using logistic regression (3.2).

In the period from August 2017 to July 2018, the proportion of chickens with *Campylobacter* spp. levels at >1000 cfu per g ranged from 13 to 16 % across the groups of stores recognised as smaller retail shops (Table 2). There was no significant difference between these groups of stores, neither in relation to the proportions of chicken with > 1000 cfu per g of *Campylobacter* spp. nor with respect to the proportion positive (ie samples with > 10/g) (Table 2).

Table 1. Numbers of *Campylobacter* spp. in whole fresh chicken collected from all shop types, including major retailers during the first sampling period[a], in relation to retailer.

	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		**10-99**		**100-1000**		**> 1000**	
Retailer	**n[b]**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
Aldi	53	50 (41-60)	30	29 (20-38)	20	19 (12-28)	2	2 (0-7)
Asda	35	33 (24-42)	32	30 (21-40)	34	32 (23-41)	6	6 (2-12)
Co-op	51	51 (41-61)	37	37 (28-47)	12	12 (6-20)	0	0 (0-4)
Lidl	47	47 (37-57)	22	22 (14-31)	23	23 (15-32)	9	9 (4-16)
M&S	30	30 (21-40)	29	29 (21-39)	32	32 (23-42)	8	8 (4-15)
Morrisons	59	58 (48-68)	28	27 (19-37)	11	11 (6-18)	4	4 (1-10)
Sainsbury's	46	41 (32-51)	32	29 (20-38)	18	16 (10-24)	16	14 (8-22)
Tesco	50	46 (36-57)	40	37 (28-46)	15	14 (8-32)	4	4 (1-9)
Waitrose	77	73 (64-81)	21	20 (13-29)	7	7 (3-13)	0	0 (0-3)
Smaller chains and others[c]	4	8 (2-18)	14	26 (15-40)	20	38 (25-52)	15	28 (17-42)
Butchers	10	20 (10-33)	15	29 (17-44)	19	37 (24-52)	7	14 (6-26)
Total	462	44 (41-47)	300	29 (26-32)	211	20 (18-23)	71	7 (5-9)

[a]Samples were collected from August to October 2017 except for a small proportion collected in early November (1 Morrisons, 3 Sainsburys, 2 Tesco and 8 Waitrose) and early December (n = 2 for each of Co-op, Lidl and M&S) to ensure a sufficient sample was tested from all the major retailers.
[b]n = Number of samples
[c]These shops included smaller retail chains of stores (e.g. Iceland, Budgens etc.) and independent shops but not shops recognised as butchers.

The proportion of highly contaminated chickens from amongst the groups of stores recognised as smaller retail shops/butchers was similar with no significant improvement seen when comparing the results from the first sampling period to results for the entire sampling year for these types of shops (Table 1 and Table 2).

Table 2. Numbers of *Campylobacter* spp. in whole fresh chicken collected from smaller retail shops from August 2017 to July 2018.

	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		**10-99**		**100-1000**		**> 1000**	
Retail store type	**n[a]**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
Smaller chains	62	21 (16-26)	90	30 (25-36)	100	33 (28-39)	48	16 (12-21)
Butchers	87	29 (24-34)	64	21 (17-25)	108	36 (30-41)	44	15 (11-19)
Others[b]	58	26 (20-32)	64	28 (23-35)	75	33 (27-40)	29	13 (9-18)
Total	207	25 (22-28)	218	26 (23-29)	283	34 (31-37)	121	15 (12-17)

[a]n = Number of samples

[b]Others included farm shops, markets and independent others excluding butchers. Within this category there were, however, 15 chickens from major retailers labelled explicitly as Halal and these were included here as Halal chicken were considered part of the less mainstream market the sample is attempting to represent – and some major retailers do supply to the Halal chicken market.

3.1.2 Numbers of *Campylobacter* spp. in chicken skin samples in relation to chicken rearing regime

The rearing regime for chickens examined was recorded, and Table 3 summarises the levels of *Campylobacter* spp. detected in relation to whether the birds were reared without access to range (termed standard) or as free-range or as organic for all samples tested (Table 3). Fewer samples from chickens reared using free range or organic production methods were examined reflecting their lower market share. This meant that, unless very large differences in contamination rates were present in these chicken types, it would not be possible to ascertain significant differences. Nevertheless, within this dataset, no significant differences in the proportion of highly contaminated chickens between the three types of chickens were found but note the wide 95 % confidence intervals.

In the samples collected across an entire year from smaller retail shops there was also no significant differences in the proportion of highly contaminated chickens between the three types of chickens (Table 4).

Table 3. Numbers of *Campylobacter* spp. in whole fresh retail chicken in relation to bird rearing regime (all samples included).

Rearing regime	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		**10-99**		**100-1000**		**>1000**	
	n[a]	**% (95% CI)**	n	**% (95% CI)**	n	**% (95% CI)**	n	**% (95% CI)**
Standard	403	44 (41-47)	267	29 (26-32)	186	20 (18-23)	66	7 (6-9)
Free Range	56	50 (41-60)	31	28 (20-37)	20	18 (11-26)	4	4 (1-9)
Organic	3	27 (6-61)	2	18 (2-52)	5	45 (17-77)	1	9 (0-41)

[a]n = Number of samples

Table 4. Numbers of *Campylobacter* spp. in whole fresh chicken collected from collected from smaller retail shops from August 2017 to July 2018, in relation to bird rearing regime.

Rearing regime	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		**10-99**		**100-1000**		**>1000**	
	n[a]	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
Standard	179	26 (23-29)	176	25 (22-29)	236	34 (30-38)	103	15 (12-18)
- of which Halal	23	30 (20-41)	16	21 (12-32)	28	36 (26-48)	10	13 (6-23)
- of which Kosher	6	40 (16-68)	2	13 (2-40)	6	40 (16-68)	1	7 (2-32)
Free Range	28	21 (14-29)	42	32 (24-40)	45	34 (26-43)	18	14 (8-21)
Organic	0	-	0	-	2	-	0	-

[a]n = Number of samples

3.1.3 Numbers of *Campylobacter* spp. in chicken skin samples in relation to chicken processor approval number.

There were significant differences in the distribution of contamination of chickens with *Campylobacter* spp. between the different processor approval numbers (i.e. slaughter house premises) during the first sampling period where samples from major retailers dominated (Table 5).

The percentage of chickens with >1000 cfu of *Campylobacter* spp. per g ranged from 1 % for approval number 9502 to 19 % for approval number 5007. Approval number 9502 produced significantly ($p < 0.001$; Fishers exact test) fewer highly contaminated chickens compared to the average for all approval numbers. The group of 'other' production premises (these premises tended to represent smaller premises and fewer than 50 samples were tested from these) and approval number 5007 produced significantly ($p < 0.001$; Fishers exact test) more highly contaminated chickens compared to the average of all samples tested.

Table 5. Numbers of *Campylobacter* spp. in whole fresh chicken collected from all shop types, including major retailers during the first sampling period[a], in relation to processor.

Processor Approval number	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		10-99		100-1000		>1000	
	n[b]	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
1100	34	68 (53-80)	8	16 (7-29)	6	12(5-24)	2	4 (0-14)
2037	60	53 (43-63)	42	37 (28-47)	10	9 (4-16)	1	1 (0-5)
3005	28	49 (36-63)	12	21 (18-34)	16	28 (17-42)	1	2 (0-9)
3007	25	34 (23-46)	21	28 (19-40)	24	32 (22-44)	4	5 (1-13)
3011	42	58 (46-70)	22	31 (2—43)	7	10 (4-19)	1	1 (0-8)
4014	46	56 (45-67)	26	32 (22-43)	8	10 (4-19)	2	2 (0-9)
5007	2	4 (0-13)	12	24 (13-37)	23	45 (31-60)	14	27 (16-42)
5011	52	32 (25-40)	62	38 (31-46)	38	23 (17-31)	11	7 (3-12)
8005	55	40 (32-49)	39	28 (21-37)	32	23 (16-31)	12	9 (5-15)
9502	94	75 (66-82)	25	20 (13-28)	7	6 (2-11)	0	0 (0-3)
Other code[c]	21	19 (12-27)	30	27 (19-36)	39	35 (26-45)	21	19 (12-27)
Not Available[d]	3	43	1	14	1	14	2	29
Total	462	44 (41-47)	300	29 (26-32)	211	20 (18-23)	71	7 (5-9)

[a]Samples were collected from August to October 2017 except for a small proportion collected in early November (1 Morrisons, 3 Sainsburys, 2 Tesco and 8 Waitrose) and early December (n = 2 for each of Co-op, Lidl and M&S) to ensure a sufficient sample was tested from all the major retailers.

[b]n = number of samples

[c]Samples listed within the 'Other code' category had < 50 chickens from a processor sampled. A list of approved premises codes can be found on the FSA website http://www.food.gov.uk/enforcement/sectorrules/meatplantsprems/meatpremlicence

[d]For these samples the shop was unable to provide the processor approval number.

In the samples collected across the entire year from smaller retailer shops there appeared to be differences in the proportion of highly contaminated chickens between the processors, however, the number of samples collected from each processor was small which meant only large differences may be detected (Table 6). Approval number 3011 produced significantly ($p < 0.05$; Fishers exact test) fewer highly contaminated chickens compared to the average for all samples. There were no significant differences in the proportions of highly contaminated chickens for any

of the remaining production premises compared to the average for all production premises (Fishers exact test).

Table 6. Numbers of *Campylobacter* spp. in whole fresh chicken collected from smaller retail shops from August 2017 to July 2018, in relation to processor.

Processor Approval number	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		10-99		100-1000		>1000	
	n[a]	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
5007	44	16 (12-21)	85	31 (25-37)	101	37 (31-42)	46	17 (12-22)
5003	14	24 (14-37)	11	19 (10-31)	20	34 (22-48)	14	24 (14-37)
8013	8	16 (7-29)	16	31 (19-46)	17	33 (21-48)	10	20 (10-33)
5464	8	19 (9-34)	18	43 (28-59)	12	29 (16-45)	4	10 (3-23)
3011	13	45 (26-64)	11	38(21-58)	5	17 (6-36)	0	0 (0-12)
1007	7	27 (12-48)	3	12 (2-30)	10	38 (20-59)	6	23 (9-44)
4702	15	60 (39-79)	6	24 (9-45)	3	12 (3-31)	1	4 (1-20)
9554	6	24 (9-45)	4	16 (5-36)	11	44 (24-65)	4	16 (5-36)
Other codes[b]	68	30 (24-37)	49	22 (17-28)	82	36 (30-43)	26	12 (8-16)
Not Available[c]	24	34 (23-46)	15	21 (12-32)	22	31 (21-43)	10	14 (7-24)
Total for all codes	207	25 (22-28)	218	26 (23-29)	283	34 (31-37)	121	15 (12-17)

[a]n = number of sample
[b]Samples listed within the 'Other code' category had < 25 chickens from a processor sampled. A list of approved premises codes can be found on the FSA website http://www.food.gov.uk/enforcement/sectorrules/meatplantsprems/meatpremlicence
[c]For these samples the shop was unable to provide the processor approval number

3.1.4 Numbers of *Campylobacter* spp. in whole fresh chicken in relation to sampling period (in samples collected from smaller retail shop from August 2017 to July 2018).

The proportion of samples with > 1000 cfu/g of *Campylobacter* spp. was not significantly different between the different sampling periods for the samples collected from an entire year from the smaller retail shops (Table 7). The proportion of samples with < 10 cfu/g of Campylobacter spp. was highest in the third sampling period (Table 7).

Table 7. Numbers of *Campylobacter* spp. in whole fresh chicken collected from smaller retail shops, in relation to sampling period.

	cfu of *Campylobacter* spp. per g chicken skin sample			
	<10		**>1000**	
Sampling period (months)	**n**	**% (95% CI)**	**n**	**% (95% CI)**
1 (Aug/Sep/Oct 2017)	14	14 (8-22)	22	22 (14-31)
2 Nov/Dec 2017 & Jan 2018	26	19 (13-26)	24	17 (11-25)
3 (Feb/Mar/Apr 2018)	83	29 (23-34)	42	14 (11-19)
4 (May/Jun/Jul 2018)	77	26 (21-31)	32	11 (7-15)

3.1.5 Numbers of *Campylobacter* spp. in whole fresh chicken in relation to chicken weight

Chickens were assigned into three weight categories defined by arbitrary weight ranges based on reviewing weights of chickens described as ‘small’ or ‘medium’ or ‘large’. Assignment of a size category to the chicken purchased enabled analysis to determine whether size, which may be linked to the age of the chicken at slaughter, was associated with the level of *Campylobacter* spp. present.

Using these categories, there was no statistically significant effect of chicken weight on the proportion of samples with >1000 cfu of *Campylobacter* spp. per g during the first sampling period where samples from major retailers were included (Table 8).

Table 8. Numbers of *Campylobacter* spp. in chicken collected from all shop types, including major retailers in the first sampling period, in relation to chicken weight.

Chicken weight	**cfu of *Campylobacter* spp. per g chicken skin sample**							
	<10		**10-99**		**100-1000**		**>1000**	
	n[a]	**% (95% CI)**	n	**% (95% CI)**	n	**% (95% CI)**	n	**% (95% CI)**
Small (<1400 g)	160	45 (40-51)	96	27 (23-32)	67	19 (15-24)	29	8 (5-12)
Medium (1400-1750 g)	226	45 (41-50)	152	30 (26-35)	96	19 (16-23)	27	5 (4-8)
Large (> 1750 g)	75	39 (33-47)	52	27 (21-34)	48	25 (19-32)	15	8 (4-13)

[a]n = number of sample; no weight data was available for one chicken.

For the samples obtained for an entire year from smaller retailer shops only there was a statistically significantly higher proportion of samples with >1000 cfu of *Campylobacter* spp. per g in the larger chickens (Table 9). This was also true when all samples tested in the 4th survey year were analysed together and in total 15 % of the large chickens were in the highly contaminated category compared to 7 and 9 % for medium and small chickens, respectively (results not shown).

Table 9. Numbers of *Campylobacter* spp. in chicken collected from shops not part of a major retail chain from August 2017 to July 2018 in relation to chicken weight.

Chicken weight	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		10-99		100-1000		>1000	
	n[a]	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Small (< 1400 g)	75	34 (28-41)	45	20 (15-26)	71	32 (26-39)	29	13 (9-18)
Medium (1400-1750 g)	78	27 (22-33)	84	29 (24-35)	92	32 (27-38)	31	11 (8-15)
Large (> 1750 g)	48	15 (12-20)	85	27 (12-33)	117	38 (32-43)	61	20 (15-24)

[a]n = number of sample no weight data was available for 6 chickens.

3.1.6 Numbers of *Campylobacter* spp. in chicken skin samples in relation to days of shelf-life remaining

Chickens were tested with up to nine days of remaining shelf-life and assigned into three categories each defined by an arbitrary number of shelf-life days remaining. At testing, the most frequent number of days of shelf-life remaining was 4-7 days.

Using these categories, there was no statistically significant effect of days of shelf-life remaining at testing on the proportion of samples with >1000 cfu of *Campylobacter* spp. per g nor was there an effect for the proportion positive (ie samples with > 10/g) during the first sampling period where samples from major retailers were included (Table 10). This was supported by the logistic regression analysis results (section 3.2).

For the samples obtained for an entire year from smaller retailer shops there was no statistically significant effect of days of shelf-life remaining on the proportion of samples with >1000 cfu of *Campylobacter* spp. per g nor in the proportion positive (ie samples with > 10/g) (Table 11).

In summary, for this data there was no trend suggesting that a high-level contamination was more likely in samples with the longest shelf-life remaining at testing.

Table 10. Numbers of *Campylobacter* spp. in chicken collected from all shop types, including major retailers in the first sampling period[a], in relation to days shelf-life remaining.

Remaining shelf-life in days[b]	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		10-99		100-1000		>1000	
	n	% (95 % CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
0-3	127	47 (40-53)	76	28 (23-34)	53	19 (15-25)	17	6 (4-10)
4-7	245	37 (33-41)	196	29 (26-33)	130	19 (17-23	96	14 (12-17)
> 7	38	38 (28-48)	27	27 (9-37)	27	27 (18-37)	8	8 (4-15)

[a]Samples were collected from August to October 2017 except for a small proportion collected in early November (1 Morrisons, 3 Sainsburys, 2 Tesco and 8 Waitrose) and early December (n = 2 for each of Co-op, Lidl and M&S) to ensure a sufficient sample was tested from all the major retailers.
[b]There was no shelf-life date provided for 4 samples.

Table 11. Numbers of *Campylobacter* spp. in chicken collected from shops not part of a major retail chain from August 2017 to July 2018 in relation to days of remaining shelf-life.

Remaining shelf-life in days	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		10-99		100-1000		>1000	
	n	% (95 % CI)	n	% (95 % CI)	n	% (95 % CI)	n	% (95 % CI)
0-3	102	26 (22-31)	98	25 (21-30)	129	34 (29-38)	56	15 (11-18)
4-7	61	21 (16-26)	84	29 (24-35)	98	34 (28-40)	47	16 (12-21)
> 7	9	21 (10-36)	12	28 (15-44)	18	42 (27-58)	4	9 (3-22)
Not available	35	32 (23-41)	24	22 (14-30)	38	34 (25-44)	14	13 (7-20)

3.1.7 Other factors

Whilst the protocol stipulated to test a 10 g neck-skin sample not all chickens had sufficient neck-skin available for 10 g to be tested and were then tested with sample weights from 2 to < 10 g. The average grams of neck-skin in samples did not differ significantly between retailers. While it is possible that the level of cfu of *Campylobacter* spp. per g skin may be affected by the total weight of neck-skin used, data from the previous survey year (PHE 2016) indicated that while the proportion of neck-skin influenced the contamination rate, it did not confound the association between retailer and the proportion of highly contaminated chickens found. This issue was also addressed further as part of the logistic regression analysis described below (3.2)

Some retailers consistently sold chickens packed using a modified atmosphere packaging (MAP) whilst the large majority of chickens obtained from butchers and other non-major retailers were not MAP packed. MAP packing was therefore highly correlated with retailer type. For a proportion of the chickens it proved difficult to ascertain from the packaging whether the chicken was in fact packed using MAP or not, thus making detailed analysis problematic. *Campylobacter* spp. are microaerophilic and do not tolerate atmospheric oxygen levels as effectively as aerobic organisms and it is possible that higher levels of oxygen could decrease survival (Blankenship & Craven, 1982; Grigoriadis *et al*., 1997).

3.2 Logistic regression

Analysis of the cfu of *Campylobacter* per g of chicken skin did not detect noticeable confounding factors and the multivariable logistic regression model provided very similar estimates of odds ratios to those obtained when each variable was considered in isolation in the single variable logistic regression analysis (Table 12). In the approach used for the regression the same variables were retained as used in the previous years to make the results comparable over the years.

This indicated that the variation in the percentage of chickens with the highest level of *Campylobacter* spp. contamination (over 1000 cfu/g) from the different retailers could not be explained by chicken type, time period of sampling, days of shelf-life remaining or chicken weight, and as such is likely to represent genuine variation between the retailers. The group of smaller retail outlets including independents and butchers, was significantly different to the “reference” Aldi (selected as reference as first in alphabet). It was decided that the analysis should be focused around differences between retailers, in line with the previous study data (FSA 2016).

Due to the relationship between retailers and processors it was not possible to separate any individual association they may have with high level *Campylobacter* spp. contamination. It is likely that the processor has a bearing on contamination rate and this will be manifested as variations in the contamination rate between retailers. As retailers may source chickens from multiple processors, it would be difficult for consumers to make informed choices on the basis of information about the processor and hence processor was not included in the logistic regression model.

The possible effect of the amount of neck-skin weight in the sample was examined by including this variable in the logistic regression. It was significant with an estimated odds ratio of 1.25 (95% CI 1.09 to 1.45) per g ($p = 0.001$) but this did not impact on any of the variation between retailer.

Therefore the amount of neck-skin in the sample did not confound the effect of other factors including retailer. Both present and past data have indicated that the total weight of the neck-skin sample does not confound other factors (i.e. other factors remain independently significant).

Table 12. Estimated odds ratios from multivariable logistic regression model of *Campylobacter* spp. contamination levels >1000 cfu per g chicken skin from samples collected from all shop types, including major retailers during the first sampling period.

Variable	Multivariable analysis	
	OR (95 % CI)	p-value
Retailer		<0.0001
Aldi	Reference	
Asda	2.47 (0.55 to 11.03)	
Co-op	0.22 (0.01 to 4.66)	
Lidl	4.14 (0.99 to 27.23)	
M&S	3.40 (0.80 to 14.46)	
Morrisons	2.26 (0.46 to 11.20)	
Sainsbury's	6.61 (1.68 to 25.94)	
Tesco	1.80 (0.37 to 8.73)	
Waitrose	0.23 (0.01 to 4.99)	
Other	18.30 (4.44 to 75.48)	
Butchers	6.86 (1.51 to 31.24)	
Chicken type		0.37
Standard	Reference	
Free Range	0.60 (0.22-1.65)	
Organic	1.37 (0.20-9.40)	
Time period[a]		0.12
AUG	Reference	
SEP	1.82 (0.88-3.78)	
OCT	2.38 (1.15-4.89)	
NOV	4.09 (0.51-33.08)	
DEC	5.40 (0.69-42.36)	
Remaining shelf-life		0.36
Per additional day	0.77 (0.44-1.35)	
Weight		0.78
Small <1400 g	Reference	
Medium 1400-1750 g	0.82 (0.45-1.48)	
Large >1750 g	0.84 (0.42-1.68)	

[a]A smaller number of samples were tested in the months of November and December 2017.

However, we cannot rule out that total sample weight, likely to be associated with the extent to which a processor may remove neck-skin, may have impacted the effect size of other factors, hence caution has to be applied when comparing results.

3.3 *Campylobacter* species isolated from skin samples of fresh whole UK produced chicken at retail

From all samples tested, a total of 1024 isolates were subjected to *C. jejuni/C. coli* speciation testing. *C. jejuni* alone was found in 78 %, *C. coli* alone in 16 % and both species in 6 % of samples (Table 13). No speciation test was available for 90 samples (8 % of the total number of *Campylobacter*-positive samples) due to loss of isolate viability. The proportion of samples *C. coli* was isolated from where chickens were reared as free-range or organic (all chicken reared as organic are reared with access to range) was significantly higher (Table 13) compared to samples from chickens reared without access to range (referred to as standard rearing; $p < 0.001$; Fisher's exact).

Table 13. *C. jejuni* and *C. coli* isolates from retail chicken skin samples (all samples) in relation to bird rearing regime.

Species detected	% of samples with *Campylobacter* species (no. of samples)			
		Chicken rearing method		
	All samples	**Standard rearing (no access to range)** (n)	**Free range** (n)	**Organic** (n)
***C. jejuni* only**	78 (800)	82 (715)	56 (80)	63 (5)
***C. coli* only**	16 (166)	13 (116)	34 (48)	25 (2)
C. jejuni* and *C. coli	6 (58)	5 (43)	10 (14)	12 (1)

In the samples tested from non-major retail shops, spanning an entire year from August 2017 to July 2018, *C. jejuni* was slightly less prevalent during the summer period compared to the rest of the year but this difference was not statistically significant (Fisher's exact test; Table 14).

There was evidence of differences in the proportion of *C. coli/C. jejuni* isolates found between different approval numbers. In particular, a higher proportion of *C. coli* appeared to be isolated among certain approval numbers with the highest proportion seen for an approval number known to predominantly produce free-range chickens (Table 15). For example, the proportion of samples *C. coli* was isolated from was significantly higher for approval number 5450 but significantly lower for approval number 2037 (Table 15) compared to average ($p< 0.05$ and $p<0.001$, respectively; Fisher's exact test).

Table 14. Distribution of *C. jejuni* and *C. coli* isolates from chicken skin samples collected from smaller chains and others in relation to season.

	% of samples with *Campylobacter* species (no. of samples)	
Species detected	**Season**	
	Summer (August 2017 and June & July 2018) (n = 133)	**Autumn, Winter and Spring (September-December 2017 & January-May 2018)** (n = 441)
***C. jejuni* only**	66 (88)	72 (316)
***C. coli* only**	24 (32)	21 (92)
C. jejuni* and *C. coli	10 (13)	7 (33)

Table 15. *C. jejuni* and *C. coli* isolates from retail chicken (all samples) in relation to processor.

Processor Approval Number	***C. jejuni* only**		***C. coli* only**		***C. jejuni* and C. coli**	
	%	**No. of samples**	**%**	**No. of samples**	**%**	**No. of samples**
1100	94	16	6	1	0	0
2037	98	45	0	0	2	1
3005	93	25	4	1	4	1
3007	90	46	8	4	2	1
3011	95	36	5	2	0	0
4014	94	29	6	2	0	0
5003	69	29	19	8	12	5
5007	71	154	19	42	9	20
5008	75	12	13	2	13	2
5011	83	84	14	14	3	3
5464	85	33	10	4	5	2
5450	59	10	35	6	6	1
8005	88	65	8	6	4	3
9502	90	26	7	2	3	1
9509	84	21	16	4	0	0
9554	68	13	26	5	5	1
Other code[#]	64	121	29	54	7	13
Not Available[§]	73	35	19	9	8	4
All processor approval numbers	78	800	16	166	6	58

[§]Shop was unable to provide processor Approval number.

[#]Samples listed within the 'Other code' category had < 15 isolates from the processor sampled within the study. A list of approved premises codes can be found on the FSA website http://www.food.gov.uk/enforcement/sectorrules/meatplantsprems/meatpremlicence

4.0 Discussion

4.1 Survey results

In the first sampling period from August to October 2017 during this 4th survey year chickens were sampled from all retailer groups, including major retailers. Based on this data, *Campylobacter* spp. were detected in the majority (56 %) of chicken skin samples and 7 % of the samples had counts above 1000 cfu per g chicken skin. A very similar level of contamination was found in the previous survey year in the months from August to October 2016 where 6 % of the samples had counts above 1000 cfu per g chicken skin and *Campylobacter* spp. were detected in 59 % of samples (n = 1038). These levels of contamination are lower, however, compared to the result from the 2nd survey year in the period from August to October 2015 where 12 % of the samples had counts above 1000 cfu per g chicken skin and *Campylobacter* spp. were detected in 70 % of samples (n = 1052).

The proportion of chickens with *Campylobacter* spp. levels at >1000 cfu per g ranged from 0 to 28 % amongst the retailers tested during the first sampling period. For the nine larger retailers between 0 and 14 % of chicken had *Campylobacter* spp. levels of > 1000 cfu per g but shops that did not belong to these major retailers appearing as smaller retailers or independent shops had a higher proportion of highly contaminated chickens. It may be reasonable to hypothesise that this could relate to various factors including chicken rearing factors (e.g. access to range, farm management and biosecurity levels), processing plant factors, weight/age of bird at slaughter, shelf-life remaining at testing and season. Nevertheless, statistical analysis demonstrated that neither access to range during rearing, chicken weight at sale or days of shelf-life remaining could explain this significant difference between these types of shops compared to the major retailer stores. Further studies would be needed to provide a more comprehensive understanding of the extent to which different processors can explain the observed difference in contamination. There was significant evidence that the approval number was associated with the level of *Campylobacter* spp. found on whole fresh chicken. However, the strong relationship between retailer and approval number precluded an investigation of approval number in the logistic regression analyses. Nevertheless, the percentage of chickens with >1000 cfu per g ranged from 1 % for approval number 9502 to 19 % for approval number 5007. The latter premises and premises belonging to a group of smaller premises (for which a smaller number of samples were tested) produced more highly contaminated chickens compared to the average of all samples tested.

Chickens from smaller retail shops were tested for an entire year, from August 2017 to July 2018 as the FSA decided this warranted continued monitoring due to the lack of improvement for this group of retail shops. *Campylobacter* spp. were detected in 75 % of these chicken skin samples obtained from non-major retailer shops only, and 15 % of the samples had counts above 1000 cfu per g chicken skin. The proportion of chickens with *Campylobacter* spp. levels at >1000 cfu per g ranged from 13 to 16 % across the groups of stores recognised as smaller retail shops. There appeared to be differences in the proportion of highly contaminated chickens between the processors, however, the number of samples collected from each processor was small which meant only large differences may be detected.

Whilst there was no evidence that free-range or organic chickens were more highly contaminated than standard birds, this finding should be treated with caution as low numbers of free-range and organic chickens were examined due to their low overall market share. Their corresponding confidence intervals were wide and would therefore only be able to verify very large differences. Nevertheless, a very similar finding was made in the second and third survey years (PHE 2017).

From the majority of chicken skin samples (78 %) *C. jejuni* (only) was isolated while *C. coli* (only), was identified in 16 % of samples. Compared to previous survey years the proportion of *C. coli* was higher and this was probably related to a larger proportion of chickens obtained from smaller premises. The proportion of samples *C. coli* was isolated from where chickens were reared as free-range or organic (all chicken reared as organic are reared with access to range) was significantly higher compared to samples from chickens reared without access to range.

In the previous survey years slightly lower proportions of *C. jejuni* were found (PHE 2015, PHE 2016). In an earlier FSA commissioned survey carried out in 2007 and 2008 (FSA 2009), the proportion of chickens (43 %) from which *C. jejuni* was isolated was considerably lower than in the current study. It is possible that this finding may relate to differences in the method of detection used. While this survey applied direct enumeration only, the 2007/2008 survey isolates were obtained using an enrichment method. In the CLASSP survey where enrichment culture was used, 62 % were *C. jejuni*, 32 % were *C. coli* and both species were detected in 6 % (CLASSP Project Team 2010). In the 2001 retail survey (FSA 2003), 25 % of isolates were *C. coli* only using an enrichment method. The proportion of human *C. jejuni* and *C. coli* strains in UK has been reported as approximately 90 % and 10 %, respectively (CLASSP Project Team 2010).

Recent slaughter house survey data for *Campylobacter* spp. on chicken carcasses tested after slaughter (and just before being put on retail sale) undertaken by the Animal and Plant Health Agency found a decrease in the proportion of highly contaminated carcases from 28.5 % in 2012-15 to 25.1 % in 2016-17 (FSA 2015c). While the levels of campylobacters on chickens just after slaughter are expected in general to be higher compared to what they are subsequently at retail, it is not clear why the decline for retail chicken appears to be so much more pronounced. Further analysis would be needed to ascertain if differences in sample weight or what proportion of chicken types were included in the testing e.g. in terms of weight could explain any disproportionate trends unlikely to be due the natural decline of viable campylobacters as expected during shelf-life.

In summary, the proportion of chicken at retail sale in the UK that are contaminated with a high level of *Campylobacter* spp. has decreased. However, the proportion of highly contaminated chickens from smaller retail shops remains high and suggests that more needs to be done to achieve better control of *Campylobacter* spp. in this part of the sector. Overall, however, the data from this and the previous survey years has demonstrated a significant decline in the level of highly contaminated fresh whole UK retail chicken. The FSA has indicated that the average retail proxy for the proportion of highly contaminated retail chickens should be less than 7 % and continued monitoring can demonstrate that this decline is sustained.

4.2 Human *Campylobacter* spp. infections in the UK

The EFSA Scientific Opinion published in 2011 (EFSA 2011) suggested that reducing the numbers of *Campylobacter* spp. on carcases by more than 99 % would reduce the public health risk by more than 90 %.

The reporting rate for *Campylobacter* spp. decreased in the UK from 109.2 per 100,000 population in 2014 to 89.9 per 100,000 in 2016. The rate of reported *Campylobacter* infections in England as at the lowest rate in 2016 since 2006, and remains below the rate observed in Wales and Scotland (Table 15). However, the rate of reported *Campylobacter* infections in England and Wales has increased again in 2017 and 2018. The reasons for this increase remains unclear but may relate to changes in the relative importance of foodborne compared to non-foodborne transmission routes, an increased transmission from non-chicken sources and /or other factors including changes in population immunity and the proportion of cases that maybe travel-associated.

Northern Ireland continues to report rates lower than the rest of the UK while Wales has continued to report the highest rates of infection except for 2018 (Table 16). The rate of reported *Campylobacter* infections in both Scotland and Wales also declined from 2014 to 2016.

Table 16. Number and rate* of reported *Campylobacter* spp. infections in the United Kingdom and by country per 100,000 population, 2006-2018.

Year	England		Wales		Scotland		Northern Ireland		United Kingdom	
	N	Rate*	N	Rate*	N	Rate*	N	Rate*	n	Rate*
2006	43806	86.0	2942	98.5	4853	94.5	934	53.6	52535	86.4
2007	48622	94.6	3209	106.7	5190	100.4	881	50.0	57902	94.4
2008	47096	90.9	2795	92.4	4866	93.5	843	47.4	55600	89.9
2009	54438	104.3	3247	106.8	6398	122.3	974	54.3	65057	104.5
2010	59200	112.5	3388	111.1	6582	125.1	1036	57.4	70206	111.9
2011	60616	114.1	3911	127.7	6366	120.1	1171	64.5	72064	113.9
2012	61255	114.5	3789	123.3	6333	119.2	1205	66.1	72582	113.9
2013	55906	103.8	3134	101.7	6163	115.7	1349	73.7	66552	103.8
2014	58782	108.2	3712	120.1	6636	124.1	1415	76.9	70545	109.2
2015	51912	95.6	3795	122.7	6184	115.6	1320	71.7	63211	97.9
2016	48884	88.4	3498	112.4	5294	98.0	1258	67.6	58933	89.8
2017	53068	95.4	3661	117.1	5796	106.8	1421	76.0	63946	96.8
2018*	57674	103.7	2625	84.0	-	-	-	-	-	-

*Rates were calculated based on the ONS 2016 mid-year population estimates; data for 2018 are provisional and not available for some nations yet.

4.3 Conclusions

- The proportion of fresh whole chicken on retail sale in the UK that are contaminated with the highest level of *Campylobacter* spp. has on average, decreased from 2014, but for chickens from smaller retailer shops no decrease has been observed.

- Continued monitoring will be required to demonstrate a sustained decline.

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6.0 Appendices

6.1 Appendix I Survey protocol

6.2 Appendix II Survey year 4 data

6.3 Appendix III Table 1a

Table 1a. Numbers of *Campylobacter* spp. in whole fresh chicken collected from all shop types, including major retailers during August to October 2017, in relation to retailer.

	cfu of *Campylobacter* spp. per g chicken skin sample							
	<10		**10-99**		**100-1000**		**> 1000**	
Retailer	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**	**n**	**% (95% CI)**
Aldi	53	50 (41-60)	30	29 (20-38)	20	19 (12-28)	2	2 (0-7)
Asda	35	33 (24-42)	32	30 (21-40)	34	32 (23-41)	6	6 (2-12)
Co-op	50	51 (41-61)	36	37 (27-47)	12	12 (6-20)	0	0 (0-4)
Lidl	47	47 (37-58)	22	22 (14-32)	22	22 (14-32)	8	8 (4-15)
M&S	28	29 (20-39)	29	30 (21-40)	32	33 (24-43)	8	8 (4-16)
Morrisons	59	58 (48-68)	28	28 (19-38)	11	11 (6-19)	3	3 (1–8)
Sainsbury's	45	41 (32-51)	30	28 (19-37)	18	17 (10-25)	16	15 (9-23)
Tesco	48	45 (35-55)	40	37 (28-47)	15	14 (8-22)	4	4 (1-9)
Waitrose	71	73 (63-82)	21	22 (14-31)	5	5 (2-12)	0	0 (0-5)
Smaller chains and others[a]	4	8 (2-18)	14	26 (15-40)	20	38 (25-52)	15	28 (17-42)
Butchers	10	20 (10-33)	15	29 (17-44)	19	37 (24-52)	7	14 (6-26)
Total	450	44 (41-47)	297	29 (26-32)	208	20 (18-23)	69	7 (5-8)

[a]These shops included smaller retail chains of stores (e.g. Iceland, Budgens etc.) and independent shops but not shops recognised as butchers.