



6

RESISTANCE IN
ZONOTIC BACTERIA



6. Resistance in zoonotic bacteria



Highlights: As in previous years, resistance levels in *Campylobacter jejuni* isolated from humans were higher than in isolates from broilers and cattle, and among human isolates, resistance was higher in travel-associated cases compared to domestically acquired cases.

Compared to 2022, the percentage of fully sensitive *C. jejuni* increased in isolates from broilers (from 59% to 61%) and decreased in isolates from cattle (from 76% to 70%).

Erythromycin resistance remained rare in *C. jejuni* from humans (1%) and resistance was not observed in isolates from broilers or cattle.

Fluoroquinolone (ciprofloxacin) resistance remained common in *C. jejuni* isolates from human cases (54%) and broilers (34%) and increased by 7% in cattle (29%). Tetracycline resistance was common in *C. jejuni* from humans (30%) and broilers (27%), and less common in cattle (7%).

Resistance to ciprofloxacin and tetracycline in *C. coli* from pigs increased compared to the levels observed in 2021 (from 20% to 25% and 26% to 35%, respectively). Resistance to ertapenem was not observed in *C. coli* from pigs. *C. coli* isolates from humans exhibited generally more resistance than isolates from pigs, indicating that the human isolates likely originate from sources other than Danish pigs. Erythromycin resistance was seen in 11% of the tested human *C. coli* isolates.

A total of 697 human clinical *Salmonella* spp. isolates representing 88 different serotypes were tested. Most *Salmonella* spp. isolates from humans were fully sensitive (64%), while lower levels of full susceptibility were found in pigs (46%) and pork (25%).

Macrolide (azithromycin) resistance in *Salmonella* spp. remained low in isolates from human travel-associated (3%) and domestic cases (1%). No azithromycin resistance was reported in isolates from domestic pork and a single *S. Typhimurium* resistant isolate was recovered from pigs.

Resistance to ciprofloxacin in *Salmonella* spp. was observed in 15% of the isolates from humans. Ciprofloxacin resistance in *S. Typhimurium* and monophasic *S. Typhimurium* increased in 2023 (from 3% to 12% and 8% to 11%, respectively). Fluoroquinolone resistance has not been recorded in *S. Typhimurium* from Danish pork since 2007 however, a single monophasic *S. Typhimurium* isolate from pigs was resistant to ciprofloxacin in 2023.

Resistance to 3rd generation cephalosporins, cefotaxime and ceftazidime, in *Salmonella* spp. is rare in human isolates (2%), and no resistance was found in isolates from pigs and domestic pork. No carbapenem resistance (meropenem) was observed in *Salmonella* spp. from humans, pigs and domestic pork.

After a three-year decreasing trend, multidrug resistance (MDR) in *S. Typhimurium* and its monophasic variant from domestic pork increased in 2023 by 27%, with an increase in the ratio between the prevalence of other MDR profiles and the combined resistance to ampicillin, sulfamethoxazole and tetracycline (ASuT).

6.1 Resistance in zoonotic bacteria

6.1.1 Introduction to resistance in zoonotic bacteria

Zoonoses are infectious diseases transmitted between animals and humans, either through direct contact or indirectly by ingesting contaminated food or water or by contact with a contaminated environment. A description of the trends and sources of zoonoses in Denmark and national surveillance and control programmes can be found in the Annual Report on Zoonoses in Denmark 2023 [www.food.dtu.dk].

Surveillance of antimicrobial resistance (AMR) in the zoonotic bacteria *Campylobacter* and *Salmonella* from food-producing animals, food products, and humans has been part of the DANMAP programme since 1995. Phenotypic antimicrobial resistance is monitored in isolates from human clinical cases, broilers, cattle, pigs, and derived meat.

In Denmark, antimicrobials are generally not recommended for treating human patients with diarrhoea unless the illness is prolonged, or the patient is severely ill. If treatment is necessary, macrolides (azithromycin) are recommended for treating *Campylobacter* infections. No specific recommendations for antibiotic treatment exist for *Salmonella* infections in the primary sector. In hospitals, intravenous treatment is recommended for septic patients and per oral azithromycin for less severe cases. In case of prolonged or recurrent infections, a combination therapy can be used by adding ciprofloxacin or sulfamethoxazole and trimethoprim. The Register of Medicinal Product Statistics at the Danish Health Data Authority does not register the specific pathogen treated with antimicrobials.

Macrolides are often used to treat infections in food-producing animals in Denmark, particularly in pigs. Fluoroquinolones are not used in production animals, and there is a limited use of 2nd generation cephalosporins in cattle, while no use of 3rd and 4th generation cephalosporins occurs. The use of antimicrobials in the Danish poultry sector is low and limited to only a few antimicrobial classes, primarily tetracyclines (see Chapter 4, Table 4.1).

In humans, antimicrobial resistance is monitored in clinical *Salmonella* isolates and for *C. jejuni* and *C. coli*, a geographically stratified selection of clinical isolates is tested. The testing is performed in accordance with the ECDC recommendations (see Chapter 10, section 10.9). Travel histories of the patients are collected, when possible.

Campylobacter isolates were obtained from healthy animals at slaughter (caecal samples from broilers, cattle and pigs), while *Salmonella* isolates were obtained from caecal samples and carcasses of healthy pigs at slaughter. *C. jejuni* is always reported for broilers and cattle, and *C. coli* is always reported for pigs, and occasionally for broilers and cattle (see Chapter 10, Table 10.1 for further details). Since 2021, the antimicrobial susceptibility testing of *Campylobacter* and *Salmonella*

from animals and meat has been done in accordance with the Commission Implementing Decision 2020/1729/EU of 17 November 2020 on the monitoring and reporting of antimicrobial resistance in zoonotic and commensal bacteria (see Chapter 10 for further details).

6.1.2 *Campylobacter*

A total of 279 human *C. jejuni* isolates were susceptibility tested. The isolates represented 226 domestically acquired cases and 53 travel-associated cases. Additionally, 57 *C. coli* isolates were tested of which 40 and 17 isolates were from domestic and travel-associated human cases, respectively. All *C. jejuni* isolates recovered from broilers (41), cattle (174), and pigs (1) and all *C. coli* isolates from broilers (1), cattle (8) and pigs (127) were susceptibility tested.

Resistance in *Campylobacter jejuni*

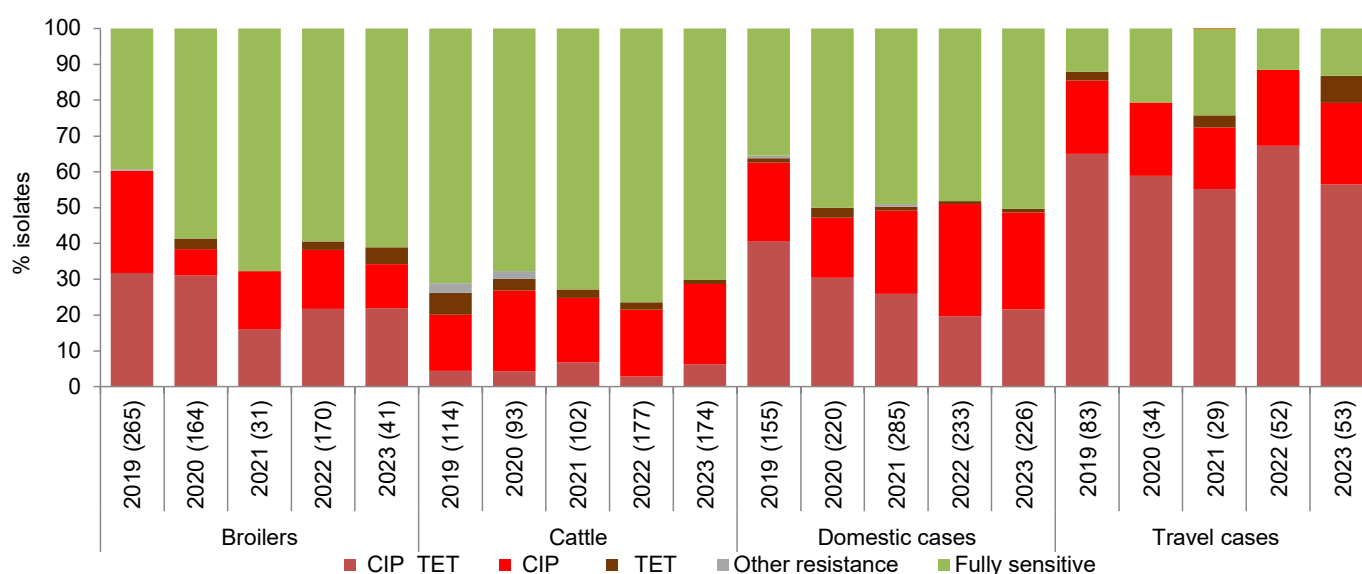
The resistance levels in *C. jejuni* isolates from humans, and Danish broilers and cattle at slaughter are presented in Table 6.1. Resistance to ciprofloxacin and tetracycline was common in isolates from humans, broilers, and cattle (Table 6.1 and Figure 6.1). Like in the previous years the resistance level to erythromycin was low in human isolates (1%) and no erythromycin resistance was observed in isolates from broilers or cattle. Resistance to chloramphenicol and gentamicin was not recorded in 2023.

Ertapenem resistance has been monitored since 2021. However, the European Committee on Antimicrobial Susceptibility Testing (EUCAST) has not proposed an epidemiological cut-off (ECOFF) or clinical breakpoint for ertapenem resistance, which is crucial for identifying whether an isolate is susceptible or resistant. The EU Reference Laboratory for AMR (EURL-AR) and the European Food Safety Authority have established a provisional ECOFF of 0.5 mg/L (Chapter 10, Table 10.2), which DANMAP adopted in 2021. Resistance levels for this antimicrobial in human and broiler isolates were in line with the findings from 2021 and 2022. A total of 6% of all isolates from humans were resistant, with domestic- and travel-related cases presenting 4% and 13% of ertapenem resistance, respectively. Of all *C. jejuni* isolates from broilers, 2% were resistant to ertapenem. Unlike in 2021 and 2022 when no ertapenem resistance was observed in *C. jejuni* isolates from cattle, in 2023, 1% of these isolates were resistant.

In 2023, 61% of *C. jejuni* from broilers, 70% from cattle and 43% from human cases were sensitive to all antimicrobials tested. The percentage of fully sensitive *C. jejuni* isolates from domestic human cases was in line with previous years. Also, resistance levels to ciprofloxacin and tetracycline were higher in infections from travel-related cases compared to domestically acquired cases (Figure 6.2). The occurrence of fully sensitive isolates was similar to that found in 2022 for *C. jejuni* isolates from broilers, while a decrease was observed among isolates from cattle (Figure 6.1).

Figure 6.1 Distribution (%) of AMR profiles in *Campylobacter jejuni* from broilers, cattle and human cases, Denmark, 2019-2023

DANMAP 2023



The number of isolates included each year is shown in parentheses. A human isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease. CIP: all isolates with ciprofloxacin resistance but not tetracycline resistance, TET: all isolates with tetracycline resistance but not ciprofloxacin resistance, CIP TET: all isolates with both ciprofloxacin and tetracycline resistance, Other resistance: all isolates without both ciprofloxacin and tetracycline resistance, Fully sensitive: all isolates susceptible to all antimicrobial agents included in the test panel. CIP TET, CIP and TET isolates may be also resistant to other antimicrobials in the test panel (see Table 6.1)

Table 6.1 Resistance (%) in *Campylobacter jejuni* isolates from broilers, cattle and human cases, Denmark, 2023

DANMAP 2023

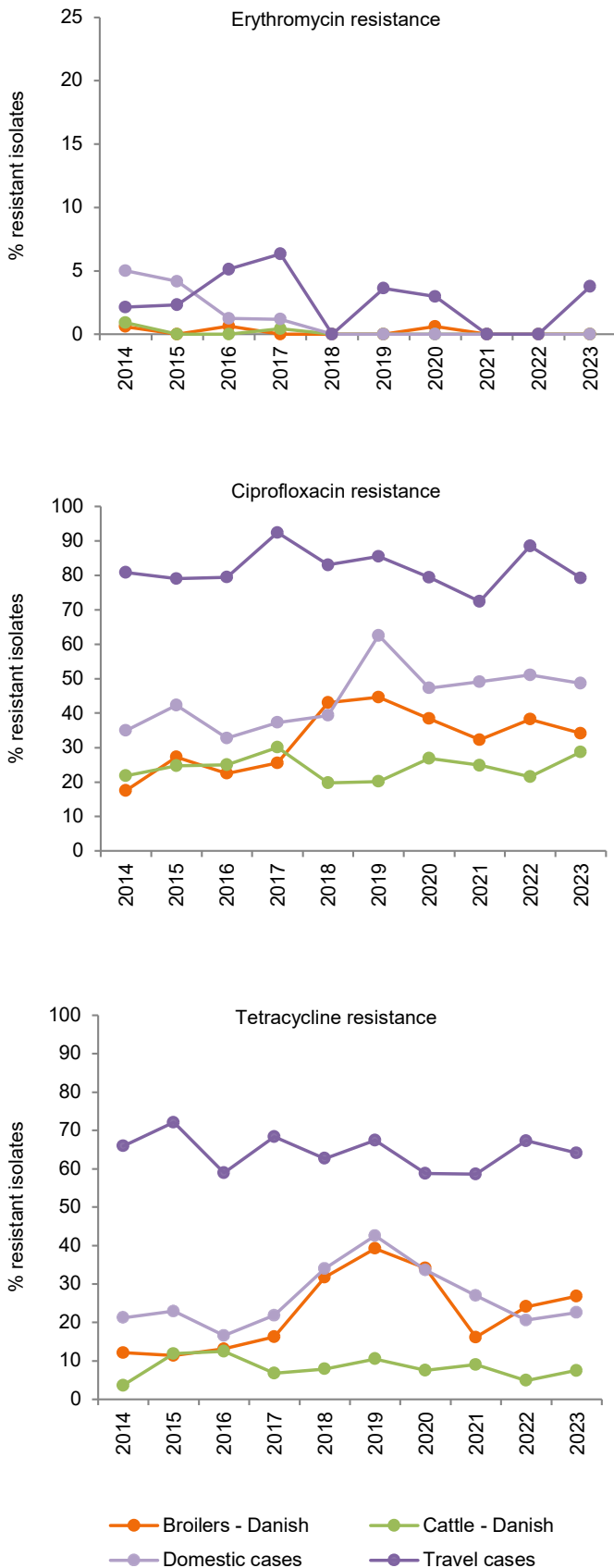
Antimicrobial agent	Broilers		Cattle		Human	
	Danish %	Danish %	Domestically acquired %	Travel abroad reported %	Total %	
Chloramphenicol	0	0	0	0	0	
Ciprofloxacin	34	29	49	79	54	
Ertapenem	2	1	4	13	6	
Erythromycin	0	0	0	4	1	
Gentamicin	0	0	0	0	0	
Tetracycline	27	7	23	64	30	
Fully sensitive (%)	61	70	50	13	43	
Number of isolates	41	174	226	53	279	

An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease

In 2023, the percentage of *C. jejuni* isolates from broilers with resistance to ciprofloxacin but not tetracycline decreased when compared to the previous year (from 16% to 12%), while the percentage of isolates with combined resistance to ciprofloxacin and tetracycline remained the same (22%). In cattle, *C. jejuni* showed an increase in the combined resistance to ciprofloxacin and tetracycline (from 3% to 6%), compared to 2022. Isolates exhibiting combined resistance towards ciprofloxacin and tetracycline were found in 22% of the human isolates from domestically acquired infections and in 57% of isolates from travel-associated cases (Fig 6.1). Resistance to tetracycline but not ciprofloxacin remained rare in isolates from animals in 2023, as did resistance to antimicrobials other than ciprofloxacin and/or tetracycline (Figure 6.1).

Ciprofloxacin resistance has overall increased in *C. jejuni* isolates from Danish broilers over the last decade until 2019. However, the trend shifted to a decrease in 2020 and 2021. In 2022 the occurrence of ciprofloxacin resistance increased again, stabilising in 2023 at a level similar to that observed in 2019 (34%; Figure 6.2). As previously observed, the shift in the trend of resistance to ciprofloxacin coincided with the shifts in resistance to tetracycline (Figure 6.2) and combined resistance to both antimicrobials (Figure 6.1). Fluoroquinolones are not used in food-producing animals in Denmark, and their use is not allowed in broiler production across the EU. This suggests that the development and spread of ciprofloxacin resistance in *C. jejuni* isolates from broilers is driven by mechanisms other than the direct use of fluoroquinolones.

Figure 6.2 Erythromycin, ciprofloxacin and tetracycline resistance (%) among *Campylobacter jejuni* from broilers, cattle and human cases, Denmark, 2014-2023 DANMAP 2023



An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease

Resistance in *Campylobacter coli*

The resistance levels in *C. coli* isolates from humans, and Danish pigs at slaughter are presented in Table 6.2. *C. coli* constitutes less than 10% of human cases and the DANMAP report has not previously focused on *C. coli* from humans. Therefore, it is not possible to compare the recorded resistance levels with previous years.

The occurrence of resistance to ciprofloxacin in *C. coli* from pigs increased when compared to the levels observed in 2021 (from 20% to 25%). Likewise, tetracycline resistance was comparatively higher (from 26% to 35%). When looking at *C. coli* isolates from humans, the resistance levels to ciprofloxacin and tetracycline are comparatively higher than those seen in pig isolates and *C. jejuni* isolates (Tables 6.1 and 6.2).

Resistance to macrolides, monitored through erythromycin, was six and 11% in isolates from pigs and humans, respectively. All erythromycin-resistant human isolates were from domestically acquired cases.

Resistance to chloramphenicol was not observed in *C. coli* isolates from pigs and humans in 2023. Similarly, resistance to gentamicin was not observed in *C. coli* from pigs and was rare in human isolates (4%). Unlike in 2021, resistance to ertapenem was not observed in *C. coli* from pigs. High resistance levels in human isolates (37%) were observed. *C. coli* isolates from human cases exhibited generally higher resistance levels than isolates from pigs, indicating that human isolates can originate from sources other than Danish pigs.

6.1.3 *Salmonella* spp.

The resistance data for *Salmonella enterica subsp. enterica* for a panel of 15 antimicrobials representing 11 antimicrobial classes are presented in Table 6.3 for pigs, domestic pork and human isolates. In 2023 a total of 697 human clinical *Salmonella* spp. isolates, representing 88 different serotypes were tested for antimicrobial susceptibility. The predominant serotypes were *S. Typhimurium* (93), monophasic *S. Typhimurium* with the antigenic formula 4,[5], 12:i:- (81), and *S. Enteritidis* (76). Except for *S. Enteritidis*, the tested isolates represented all clinical Danish isolates and included outbreak isolates. The largest outbreak encompassed 31 patients, and three other outbreaks included more than 10 patients. Also in 2023, a total of 82 and 65 *Salmonella* spp. isolates from pigs and domestic pork, respectively were tested for antimicrobial susceptibility. The most common serotypes reported in pigs were *S. Derby* (40), monophasic *S. Typhimurium* variant 4,[5], 12:i:- (31), and *S. Typhimurium* (6). Similarly, in domestic pork, the serovar distribution followed the same order, with 25, 18 and 12 *S. Derby*, monophasic *S. Typhimurium* variant 4,[5], 12:i:- and *S. Typhimurium*, respectively.

Table 6.2 Resistance (%) in *Campylobacter coli* from fattening pigs and human cases, Denmark, 2023

DANMAP 2023

Antimicrobial agent	Pigs		Human		Total %
	Danish %	Domestically acquired %	Travel abroad reported %		
Chloramphenicol	0	0	0	0	0
Ciprofloxacin	25	78	71	75	75
Ertapenem	0	38	35	37	37
Erythromycin	6	15	0	11	11
Gentamicin	0	3	6	4	4
Tetracycline	35	70	65	68	68
Fully sensitive (%)	53	18	24	19	19
Number of isolates	127	40	17	57	57

An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease

Most *Salmonella* spp. isolates from humans were fully sensitive (64%), while isolates from pigs showed a lower level of fully sensitive isolates (46%). Domestic pork showed a marked difference, with only 25% of the *Salmonella* spp. isolates sensitive to all antimicrobials tested. This difference can be attributed to the higher proportion of *S. Derby* from pigs when compared to domestic pork isolates, as resistance levels are usually lower in *S. Derby* compared to *S. Typhimurium* and its monophasic variant. Multidrug resistance is defined as resistance to three or more of the 11 tested antimicrobial classes. In 2023, 22% of human isolates were multidrug-resistant (MDR), with comparable levels observed in domestic and travel-associated cases. Higher MDR levels were reported in pigs (48%) and domestic pork (52%).

Since 2014, macrolide resistance in *Salmonella* has been monitored using azithromycin, which is used for the treatment of human *Salmonella* infections in Denmark. Low levels of azithromycin resistance were reported from human travel-associated (3%) and domestic cases (1%), and from pig isolates (1%), while no resistance was reported in isolates from domestic pork. Fluoroquinolones may also be used for the treatment of human *Salmonella* infections and resistance is monitored using nalidixic acid and ciprofloxacin. In 2023, resistance to ciprofloxacin was observed in 15% of the isolates from humans, while in pigs and domestic pork, resistance levels were markedly lower (1% and 0%, respectively). Resistance towards 3rd generation cephalosporins, cefotaxime and ceftazidime, was found in 2% of the human isolates, and no resistance was found in pig and domestic pork isolates. Carbapenem resistance (meropenem) was not observed in *Salmonella* spp. from humans, pigs and domestic pork. Colistin resistance was not reported in *Salmonella* spp. isolates from domestic pork and a low resistance level was found in isolates from pigs (one monophasic *S. Typhimurium* isolate) and human isolates (6%). The majority of these isolates, 37 out of 39 (95%), were *S. Enteritidis* or *S. Dublin*, which are intrinsically resistant to

colistin. Gentamicin resistance was found in 2% of the human isolates. Similar levels were observed in pigs (2%), while in domestic pork a higher level was recorded (8%). Similar amikacin resistance levels were found in human isolates (2%) however, most of the amikacin-resistant isolates exhibited MIC values close to the ECOFF. Tigecycline resistance was comparable across *Salmonella* spp. isolates from humans (3%), pigs (2%) and domestic pork (3%) however, many of these isolates were reported with MICs within one dilution range of the new ECOFF established in 2021 (ECOFF changed from MIC >1 mg/L to MIC >0.5 mg/L).

The most frequently observed resistance among isolates from humans, pigs and domestic pork was found for ampicillin (19%, 45% and 46%, respectively), tetracycline (19%, 46%, and 54%, respectively), and sulfamethoxazole (18%, 49% and 68%, respectively).

DANMAP focuses particularly on phenotypic resistance in *S. Typhimurium* and the related monophasic variant 4,[5],12:i:-, as these serotypes are predominant in clinical human isolates and isolates from food-producing animals, especially pigs. Clonal dissemination plays an important role in the occurrence of antimicrobial resistance among *S. Typhimurium* and monophasic *S. Typhimurium*. The global dissemination of genomic islands conferring resistance to ampicillin, sulfamethoxazole and tetracycline (the ASuT multidrug-resistance profile) among monophasic *S. Typhimurium* continues to contribute to a high level of multidrug-resistance among isolates from animals and humans in Denmark. In previous versions of DANMAP, the reported data included both *S. Typhimurium* and the monophasic variant with antigenic formula *S. 4, [5],12:i:-*, but **in 2023 antimicrobial resistance in these serotypes is presented separately**, unless otherwise indicated.

Table 6.3 Resistance (%) in *Salmonella* spp. isolates from pigs, domestic pork and humans, Denmark, 2023

DANMAP 2023

Antimicrobial agent	Pigs	Pork	Human		Total %
	Danish %	Danish %	Domestically acquired %	Travel abroad reported %	
Amikacin	0	2	2	2	2
Ampicillin	45	46	23	15	2
Azithromycin	1	0	1	3	1
Cefotaxime	0	0	1	3	2
Ceftazidime	0	0	1	3	2
Chloramphenicol	9	9	6	4	5
Ciprofloxacin	1	0	14	18	15
Colistin	1	0	5	5	6
Gentamicin	2	8	2	3	2
Meropenem	0	0	0	0	0
Nalidixic acid	1	0	13	17	14
Sulfamethoxazole	49	68	21	16	18
Tetracycline	46	54	22	18	19
Tigecycline	2	3	3	5	3
Trimethoprim	22	34	4	3	4
Fully sensitive (%)	46	25	65	62	64
Multidrug resistance (%)	48	52	25	24	22
Number of isolates	82	65	355	266	697

An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease. Total number of human cases includes travel cases and infections of unknown origin. An isolate is considered fully sensitive if susceptible to all antimicrobial agents included in the test panel. An isolate is categorised as multidrug resistant if resistant to three or more of the 11 tested antimicrobial classes (Chapter 10, Table 10.3)

Resistance in *S. Typhimurium* and monophasic *S. Typhimurium*

In 2023, a total of 93 *S. Typhimurium* and 81 monophasic *S. Typhimurium* from humans were susceptibility tested. Of these, 28 *S. Typhimurium* and 20 monophasic *S. Typhimurium* were from travel associated cases. Also in 2023, six and 12 *S. Typhimurium* and 31 and 18 monophasic *S. Typhimurium* isolates from pigs and Danish pork, respectively, were tested. Two monophasic *S. Typhimurium* variants with different antigenic formulas were also recovered and tested. However, results are only reported for isolates identified exactly as variant 4,[5],12:i:-.

The resistance data for *S. Typhimurium* and monophasic *S. Typhimurium* from pigs, domestic pork and human isolates are presented in Table 6.4.

Ampicillin-, sulfamethoxazole- and tetracycline resistance are common in isolates from humans, pigs and domestic pork. As in previous years, the occurrence of resistance continued to be overall higher in isolates from domestic pork than in isolates from humans. Notably, no fully sensitive isolates were observed in Danish pork in *S. Typhimurium* and the monophasic variant, contrary to the 10% observed in the previous year. The level of full sensitivity in *S. Typhimurium* isolates from pigs and human cases was 50% and 66%, respectively and

the level of full sensitivity among pig and human monophasic *S. Typhimurium* isolates was comparable at lower levels (10% and 6%, respectively).

Among monophasic *S. Typhimurium* isolates from humans, the level of resistance towards 3rd generation cephalosporins, cefotaxime and ceftazidime, was low in domestically acquired cases (2% to 4%) and higher in travel-associated cases (10%). Similarly, and as in previous years, resistance was not observed in *S. Typhimurium* and monophasic *S. Typhimurium* isolates from pigs and domestic pork (Table 6.4).

After a decreasing trend from 77% to 56% between 2020 and 2022, the occurrence of resistance to tetracycline in *S. Typhimurium* and monophasic *S. Typhimurium* from Danish pork increased markedly to 83% and 89% in 2023, respectively, and was similarly high among monophasic *S. Typhimurium* isolates from pigs (83%). However, resistance to tetracycline in *S. Typhimurium* from pigs was markedly lower (33%), but from a very small number of isolates. After a steady reduction in the use of tetracyclines in pig production observed since 2014, an increase in use has been observed in all age categories in 2022 and 2023 (see Chapter 4, Figure 4.4), which may explain the observed increase in tetracycline resistance in monophasic *S. Typhimurium* from pigs and domestic pork.

Table 6.4 Resistance (%) in *Salmonella* Typhimurium and monophasic *S. Typhimurium* isolates from pigs, domestic pork and humans, Denmark, 2023 DANMAP 2023

Antimicrobial agent	<i>S. Typhimurium</i>		Monophasic <i>S. Typhimurium</i>		<i>S. Typhimurium</i>			Monophasic <i>S. Typhimurium</i>		
	Pigs	Pork	Pigs	Pork	Human					
	Danish	Danish	Danish	Danish	Domestically acquired	Travel abroad reported	Total	Domestically acquired	Travel abroad reported	Total
	%	%	%	%	%	%	%	%	%	%
Amikacin	0	0	0	0	0	0	0	2	0	2
Ampicillin	50	42	84	94	24	11	19	91	80	89
Azithromycin	17	0	0	0	0	7	2	2	0	1
Cefotaxime	0	0	0	0	0	0	0	4	10	5
Ceftazidime	0	0	0	0	0	0	0	2	10	4
Chloramphenicol	17	8	13	22	16	4	12	11	15	11
Ciprofloxacin	0	0	3	0	15	7	12	11	15	11
Colistin	0	0	3	0	0	0	0	0	0	0
Gentamicin	0	8	6	17	0	0	0	9	10	9
Meropenem	0	0	0	0	0	0	0	0	0	0
Nalidixic acid	0	0	3	0	13	7	11	9	5	7
Sulfamethoxazole	50	92	87	100	23	36	26	73	65	72
Tetracycline	33	83	87	89	26	43	30	82	75	79
Tigecycline	0	8	3	0	3	21	9	5	5	5
Trimethoprim	33	33	26	33	3	0	2	11	5	9
Fully sensitive (%)	50	0	10	0	71	50	66	4	15	6
Number of isolates	6	12	31	18	62	28	93	56	20	81

Results are shown separately for *S. Typhimurium* and monophasic *S. Typhimurium* with antigenic formula S. 4,[5],12:i:-. Isolates from Danish pork were recovered from carcass swabs collected at slaughter. An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease. Total number of human cases includes travel cases and infections of unknown origin. An isolate is considered fully sensitive if susceptible to all antimicrobial agents included in the test panel (Chapter 10, Table 10.3)

Figure 6.3 presents the relative distribution (%) of AMR profiles for *S. Typhimurium* and monophasic *S. Typhimurium* from pigs, domestic pork and human domestic- and travel-related cases. Data are presented as combined for both *S. Typhimurium* and monophasic *S. Typhimurium* (Fig 6.3A) and separately for *S. Typhimurium* (Fig 6.3B) and monophasic *S. Typhimurium* (Fig 6.3C). Please note that the number of isolates varies and in some cases is low.

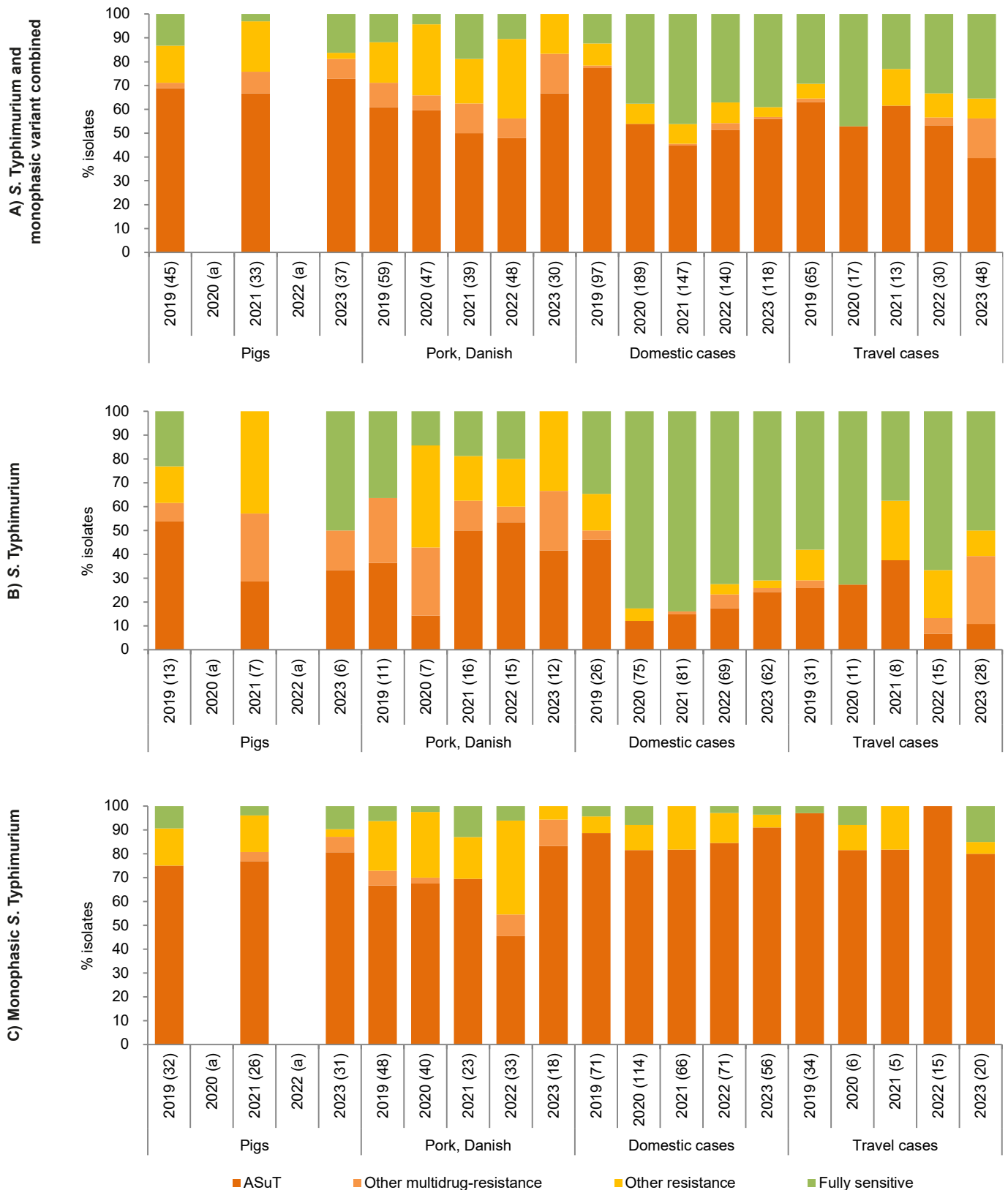
Overall, MDR in *S. Typhimurium* and monophasic *S. Typhimurium* from domestic pork showed a 27% increase compared to what was observed in 2022, with an increase in the ratio between the prevalence of other MDR profiles and ASuT. This finding is opposed to the decrease in the occurrence of MDR in *S. Typhimurium* and monophasic *S. Typhimurium* from domestic pork observed between 2019 and 2022 (Figure 6.3.A).

Most *S. Typhimurium* isolates recovered from pigs and domestic pork were resistant to several antimicrobials, with MDR levels reaching 50% and 67%, respectively. In isolates from human domestic-related cases, MDR was found at lower levels

(26%), while in travel-related cases a higher MDR level was observed (39%) (Fig 6.3B). The ASuT MDR profile was found in the majority of the MDR *S. Typhimurium* isolates from pigs, pork and human domestic cases (33%, 42% and 24%, respectively) while for human travel-related cases, other MDR profiles were more commonly found (29%; Figure 6.3.B). When looking at monophasic *S. Typhimurium*, MDR was found at markedly higher levels, with 87% and 94% of isolates from pigs and domestic pork resistant to three or more antimicrobial classes and ASuT the most found MDR profile (81% and 83%, respectively). Similarly, MDR in monophasic *S. Typhimurium* from human domestic- and travel-related cases was reported at high levels (91% and 80%, respectively), with all isolates showing the ASuT resistance profile (Figure 6.3.C).

The new approach of analysing *S. Typhimurium* and monophasic *S. Typhimurium* separately reveals marked differences in their levels of MDR and especially ASuT. These are most evident in human isolates. However, caution in data interpretation should be taken in years when a small number of isolates were recovered from domestic pork, pigs and travel-associated cases.

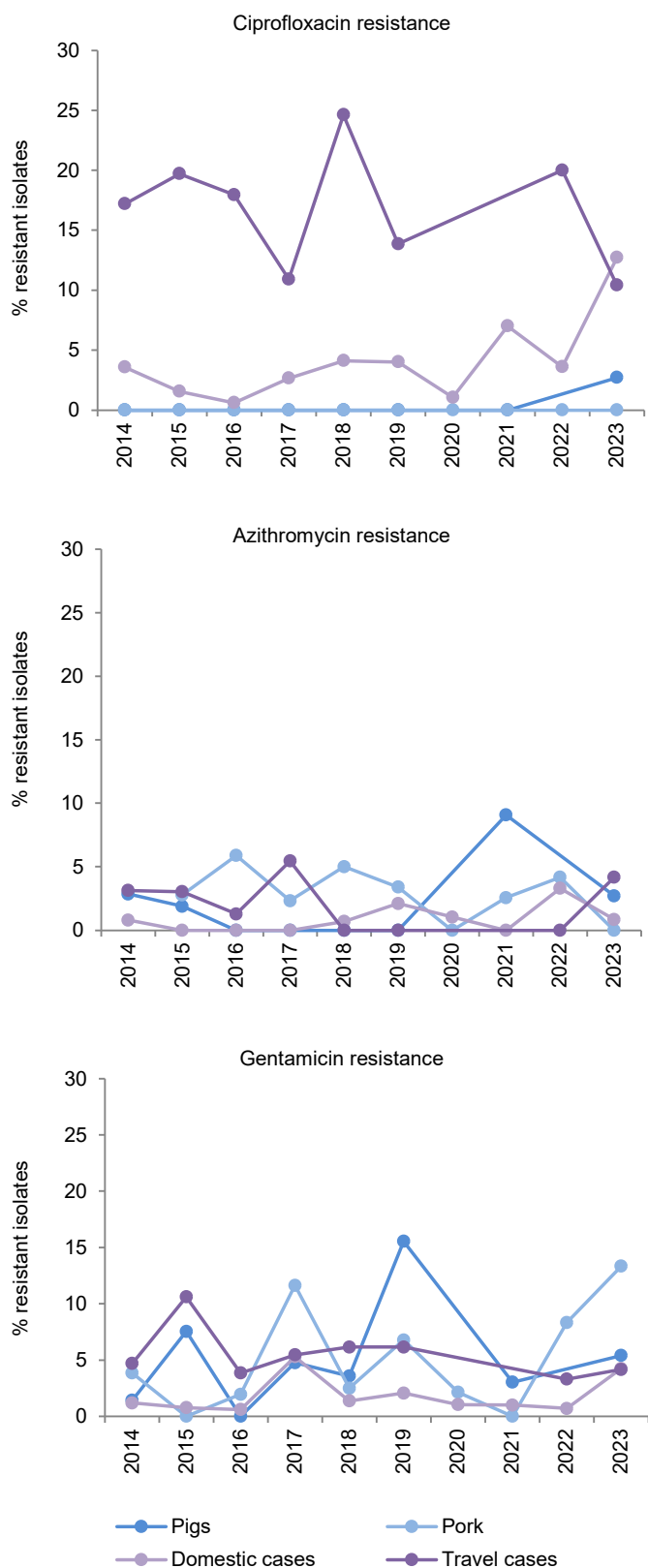
Figure 6.3 Relative distributions (%) of AMR profiles among *Salmonella* Typhimurium and its monophasic variants combined (A), *S. Typhimurium* (B) and monophasic *S. Typhimurium* (C) from pigs, pork and human cases, Denmark, 2019-2023 DANMAP 2023



Number of isolates included each year is presented in parentheses. Includes isolates verified as monophasic variants of *S. Typhimurium* with antigenic formula S. 4,[5],12:i:-. An isolate is considered fully sensitive if susceptible to all antimicrobial agents included in the test panel, and multidrug-resistant if resistant to three or more of all antimicrobial classes included in the test panel (See Chapter 10, Table 10.3). ASuT are multidrug-resistant isolates resistant to ampicillin, sulfamethoxazole and tetracycline. Caution in data interpretation should be taken in years when a small number ($n < 15$) of isolates were recovered from domestic pork, pigs and travel-associated cases.

a) No data;

Figure 6.4 Ciprofloxacin, azithromycin and gentamicin resistance (%) among *S. Typhimurium* and monophasic *S. Typhimurium* combined in isolates from pigs, domestic pork and human cases, Denmark, 2014-2023 DANMAP 2023



Includes isolates of *S. Typhimurium* and monophasic *S. Typhimurium* with antigenic formula S. 4,[5],12:i:-. An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease. Due to the low number of isolates (N<15), travel-associated cases are not shown separately for 2020 and 2021. No data available for pigs in 2020 and 2022

The levels of ciprofloxacin azithromycin and gentamicin resistance (%) among *S. Typhimurium* combined with monophasic *S. Typhimurium* from pigs, domestic pork and human cases from 2014 to 2023 are presented in Figure 6.4.

Historically, ciprofloxacin resistance has predominantly been observed in isolates from travel-associated cases, however, in 2023 the opposite was observed. Ciprofloxacin resistance was observed in 13% of the isolates from domestically-acquired infections compared to 4% in 2022 and 10% of the isolates from travel-associated cases. Ciprofloxacin resistance in *S. Typhimurium* combined with its monophasic variant from pigs and Danish pork continues to be rare. In 2023, ciprofloxacin resistance was observed in a single isolate (3%) from pigs, and it was not found among isolates from domestic pork (Figure 6.4, Table 6.4).

Resistance to azithromycin in *S. Typhimurium* including monophasic *S. Typhimurium* remains at a low level in human isolates, and in 2023 it was only found in three isolates (2%). In 2021, azithromycin resistance was detected in a higher than usual (9%) percentage of isolates from pigs. However, in 2023 the occurrence in pigs returned to the low level that had been previously observed (a single resistant isolate, corresponding to 3%), and azithromycin resistance was not observed among *S. Typhimurium* and monophasic *S. Typhimurium* from domestic pork (Figure 6.4).

The levels of gentamicin resistance have been low over the last years in *S. Typhimurium* including monophasic *S. Typhimurium* from human isolates but in 2023 an increase was observed in human monophasic *S. Typhimurium* with 9% of the isolates showing resistance (Table 6.4). In domestic pork, after a two-year decrease in 2020-2021, the occurrence of resistance to gentamicin increased in 2022 (from 0% in 2021 to 8%) and again in 2023 (to 13%). Although more moderate, resistance levels to gentamicin also increased from 3% in 2021 to 5% in 2023 among *S. Typhimurium* combined with its monophasic variant isolates from pigs (Figure 6.4).

Resistance in other *Salmonella* serotypes

The resistance levels in 76 *S. Enteritidis* isolates from humans are presented in Table 6.5. Except for ciprofloxacin, nalidixic acid and colistin, the resistance levels are generally low in isolates from domestic and travel-related cases. Resistance to ciprofloxacin was observed in 39% of the isolates, with levels in domestic cases showing higher resistance levels than in travel-associated cases (47% and 32%, respectively).

S. Derby was the second most prevalent serotype in domestic pork and pigs with 25 and 40 isolates recovered, respectively.

The occurrence of resistance in *S. Derby* is generally lower than in *S. Typhimurium* and monophasic *S. Typhimurium*. In 2023, 52% of *S. Derby* isolates from domestic pork and 70% from pigs were sensitive to all tested antimicrobials. This

represents a decrease compared to the levels found in 2022 when 69% of pork isolates were sensitive. In 2023, resistance to ampicillin, tetracycline, sulfamethoxazole, and trimethoprim increased compared to the previous year (Figure 6.5). Resistance levels in *S. Derby* from pigs were similar to those found in domestic pork (Table 6.6).

Resistance to critically important antimicrobials remained rare in 2023 in *S. Derby* isolates from pigs and domestic pork. There was no resistance to azithromycin, and only 4% of pork isolates were resistant to tigecycline. Additionally, *S. Derby* isolates from pigs and domestic pork showed no resistance to amikacin, 3rd generation cephalosporins, colistin, gentamicin, meropenem, or fluoroquinolones (Table 6.6).

Table 6.5 Resistance (%) in *Salmonella* Enteritidis isolates from humans, Denmark, 2023 DANMAP 2023

Antimicrobial agent	Human		Total %
	Domestically acquired %	Travel abroad reported %	
Amikacin	0	0	0
Ampicillin	8	11	9
Azithromycin	0	0	0
Cefotaxime	0	0	0
Ceftazidime	0	0	0
Chloramphenicol	0	0	0
Ciprofloxacin	47	32	39
Colistin	42	32	37
Gentamicin	0	0	0
Meropenem	0	0	0
Nalidixic acid	47	32	39
Sulfonamide	5	0	3
Tetracycline	3	5	4
Tigecycline	5	3	4
Trimethoprim	0	0	0
Fully sensitive (%)	39	49	45
Number of isolates	38	37	76

An isolate is categorised as domestically acquired if the patient did not travel outside Denmark one week prior to the onset of disease. The total number of human cases includes travel cases and infections of unknown origin

Figure 6.5 Resistance (%) among *Salmonella* Derby from domestic pork, Denmark, 2014-2023 DANMAP 2023

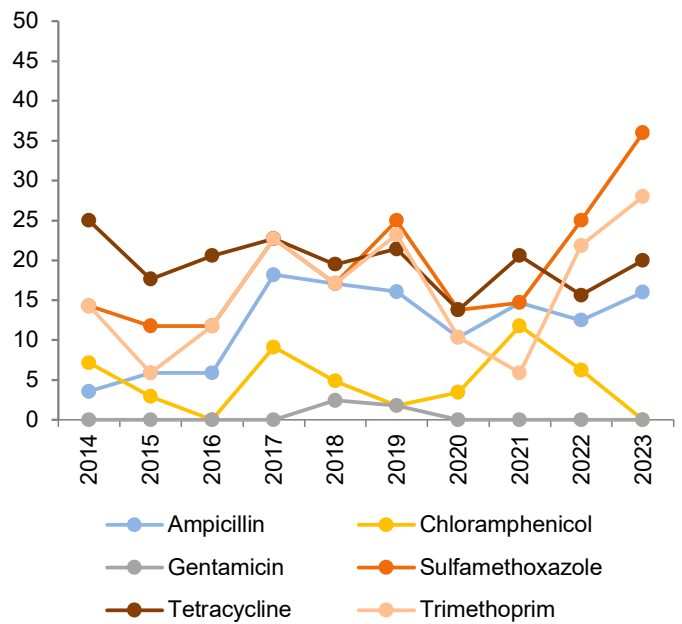


Table 6.6 Resistance (%) among *Salmonella* Derby from pigs and domestic pork, Denmark, 2023 DANMAP 2023

Antimicrobial agent	Pigs	Pork
	Danish %	Danish %
Amikacin	0	4
Ampicillin	18	16
Azithromycin	0	0
Cefotaxime	0	0
Ceftazidime	0	0
Chloramphenicol	5	0
Ciprofloxacin	0	0
Colistin	0	0
Gentamicin	0	0
Meropenem	0	0
Nalidixic acid	0	0
Sulfonamide	23	36
Tetracycline	20	20
Tigecycline	0	4
Trimethoprim	20	28
Fully sensitive (%)	70	52
Number of isolates	40	25

Isolates of Danish pork were recovered from carcass swabs collected at slaughter. An isolate is considered fully sensitive if susceptible to all antimicrobial agents included in the test panel (Chapter 10, Table 10.3)

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