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SUMMARY DANMAP 2024

Use of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from food animals, food and humans in Denmark

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The report is available from www.danmap.org.

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Read more - the DANMAP 2024 report

Further data and analyses can be found in the full DANMAP 2024 (www.danmap.org), including textboxes on topics of special interest this year.

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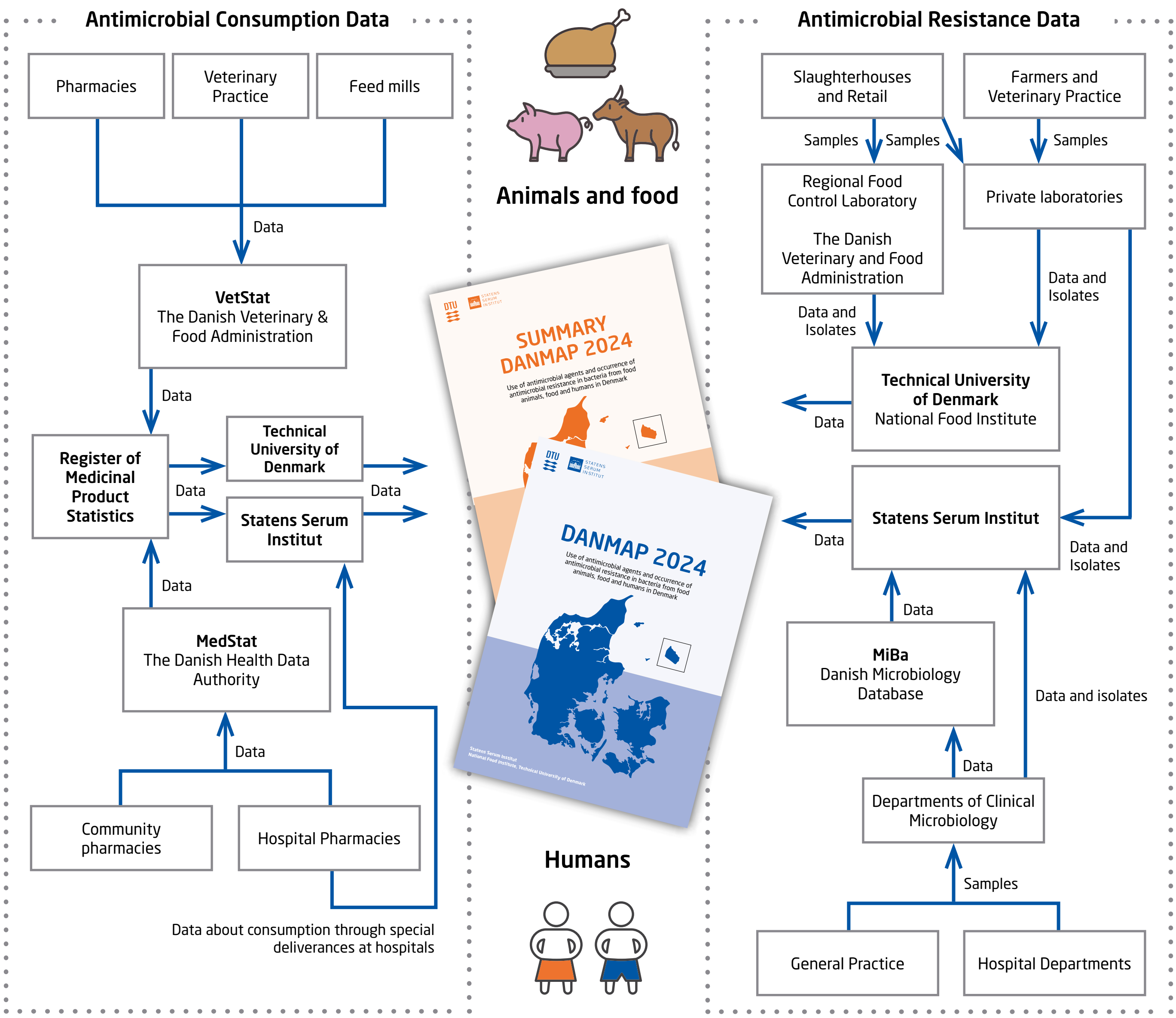
1. Introduction

The Danish integrated Antimicrobial Resistance Monitoring and Research Programme (DANMAP) is a governmentally financed surveillance programme that collects and presents antimicrobial use (AMU) and antimicrobial resistance (AMR) data in humans and animals in Denmark. The programme was established in 1995 and is based on clinical data from humans and clinical and survey data from animals.

DANMAP is based on the concept of 'One Health' – a collaborative, multidisciplinary initiative across human and animal sectors. The programme is managed by a collaborating team from the National Food Institute at the Technical University of Denmark, and the National AMR Reference Laboratory at Statens Serum Institut. The work is supported by internal and external technical experts and receives contributions from all Danish Clinical Microbiology departments, the Danish Veterinary and Food Administration and the Danish Health Data Authority. This summary report 2024 complements the more comprehensive report DANMAP 2024. It features the most important findings from the four main areas under surveillance and includes new perspectives on One Health and antimicrobial resistance. The summary aims to inform healthcare professionals, scientists, decision-makers, and everybody with an interest in antimicrobial use and resistance and the monitoring of these.

More information about the surveillance programme can be found at www.danmap.org, where you also find the full DANMAP 2024 with further data and analyses, including textboxes on topics of special interest this year. On the next page, we introduce the new action plans on antimicrobial resistance published by Danish Veterinary and Food Administration (2024) for the veterinary sector and by The Ministry of the Interior and Health (2025) for the human sector.

Figure 1.1 Organisation of DANMAP regarding data and data flow



One health action against antimicrobial resistance in Denmark

In 2017, the Ministry of Food, Agriculture and Fisheries, together with the Danish Ministry of Health, launched a joint **One Health strategy**[1] to address antimicrobial resistance (AMR). The strategy aimed to provide a framework for continued, coordinated efforts across sectors to combat resistance effectively.

A previous **One Health AMR strategy[2]**, introduced in 2010, had established a cross-sectoral coordination mechanism, the National Antibiotic Council, which was discontinued in 2019. The Council was tasked with overseeing a broad range of initiatives, including improved microbiological diagnostics, expansion of surveillance programs, development of digital tools and databases, and the creation of guidelines to mitigate the spread of resistant bacteria and support appropriate treatment in both the human and veterinary sectors. The 2017 strategy sought to build on these foundations by strengthening cross-sectoral efforts and placing greater emphasis on antimicrobial consumption, including the introduction of specific reduction targets.

In the veterinary sector, the Danish Veterinary and Food Administration's third **Action Plan against antimicrobial resistance in animals and food[3]** was launched in September 2024, under the most recent national Food and Veterinary Agreement. The action plan reaffirms its commitment to reduce, regulate, and monitor antimicrobial use and resistance and is structured around four strategic pillars: 1) strengthening surveillance by integrating whole genome sequencing and improving data granularity across species and production systems; 2) promoting responsible antibiotic use in livestock; 3) advancing targeted communication strategies to support informed choices among veterinarians, producers, and consumers; 4) prioritizing national and international collaboration and fostering cross-sectoral coordination and knowledge exchange, ensuring Denmark's active role in shaping global AMR policy and research.

As part of this renewed effort, a key target has also been set: to achieve an 8% reduction in the use of antimicrobials in pigs by the end of 2027 (see Chapter 2, Figure 2.4). This target builds on previous antimicrobial use reduction efforts. In 2017, the first action plan operationalized the One Health strategy within the veterinary and food production sectors, introducing the target to reduce overall antimicrobial use in pigs by 15% by 2018, a deadline that was later extended to 2019. Building on this foundation, a second action plan was introduced in 2021[4], reaffirming the original vision and setting the new target of a 2% annual reduction in antibiotic use in pigs from 2019 to 2022, a deadline later extended to 2023.

The new **Danish National action plan on antimicrobial resistance in humans**[5] was launched in June 2025 by The Ministry of the Interior and Health. The action plan builds on experiences from the previous action plan published in 2017[6] , as well as on the *Council Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach*[7]. The action plan differs from the previous by setting a broad framework for the Danish efforts to promote rationale use of antimicrobials and to prevent antimicrobial resistance in humans within four focus areas: (1) antimicrobial stewardship, (2) access to antimicrobials, (3) infection prevention and control and (4) international engagement. For each area, overarching political objectives and monitoring indicators are set to track progress towards the objectives. In total, 21 initiatives are suggested as concrete steps to work with the action in practice.

The action plan from 2017 presented three measurable goals to promote rational antimicrobial usage from 2017-2020, later extended to 2021. The first goal was to reduce total antimicrobial consumption in primary health care to 350 prescriptions per 1,000 inhabitants. The second was to increase the percentage share of phenoxymethylpenicillin from 31% to 36%, and the third was decrease consumption of critically important antimicrobials (fluoroquinolones, cephalosporins and carbapenems) at hospitals by 10%. The renewed action from 2025 shifts to focus on positive progress measured by specific indicators rather than reaching predefined goals. The idea is to promote sustainable change that ultimately will strengthen rational use of antimicrobials and combat antimicrobial resistance in the long term.

The two action plans call for an interdisciplinary and multisectoral approach in Denmark to make positive progress measured by the specific indicators and goals. Read more about the action plans in the full DANMAP 2024 report (www.danmap.org), textboxes 1.1 and 1.2.

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[1] www.ism.dk/Media/0/D/One%20health%20strategy%20mod%20antibiotikaresistens%20engelsk.pdf
[2] One Health AMR strategy, 2010
[3] www.foedevarestyrelsen.dk/Media/638935141545971487/AMR-handlingsplan-2024-engelsk.pdf
[4] National Action Plan, 2021
[5] www.ism.dk/Media/638918721595453894/National-action-plan-on-antimicrobial-resistance-in-humans-UK-TILG.pdf
[6] https://www.ism.dk/Media/6/2/National-handlingsplan-for-antibiotika-til-mennesker-UK%20version.pdf
[7] www.eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023H0622(01)

2. Antimicrobial consumption in animals

The surveillance of antimicrobial consumption in animals is based on sales data from pharmacies, veterinary practices, and feed mills. In the following sections, antimicrobial consumption data are presented at the national level as well as by animal species and age group levels. Since 2001, all medicines prescribed for use in animals have been recorded in Denmark´s national database, VetStat, which collects detailed data on the consumption of veterinary prescription medicines.

Since the establishment of DANMAP, numerous initiatives have been introduced to reduce antimicrobial consumption in both animals and humans, (Chapter 9, Timeline). These include discontinuation of antimicrobial agents for growth promotion, voluntary bans on the use of cephalosporins in pig and cattle production, regulatory measures governing therapeutic use and the Yellow Card Initiative. Collectively, these efforts have had a significant impact on antimicrobial consumption in animals – particularly in pigs. Figure 2.1 illustrates overall antimicrobial consumption in animals alongside key recent initiatives.

Over time, antimicrobial consumption in animals has been shaped not only by targeted risk management strategies, such as regulatory interventions and stewardship initiatives, but also by structural changes in animal production systems. Notably, increases in pig production have played a significant role in influencing overall usage patterns.

Overall antimicrobial consumption in animals

In 2024, the total consumption of antimicrobials in animals amounted to 87.46 tonnes of active compounds (Figure 2.1). This represented 63% of all antimicrobials prescribed across the human and animal sectors in Denmark.

Figure 2.1 Antimicrobial consumption in animals and recent important initiatives to reduce antimicrobial use in animals, Denmark, 1990-2024

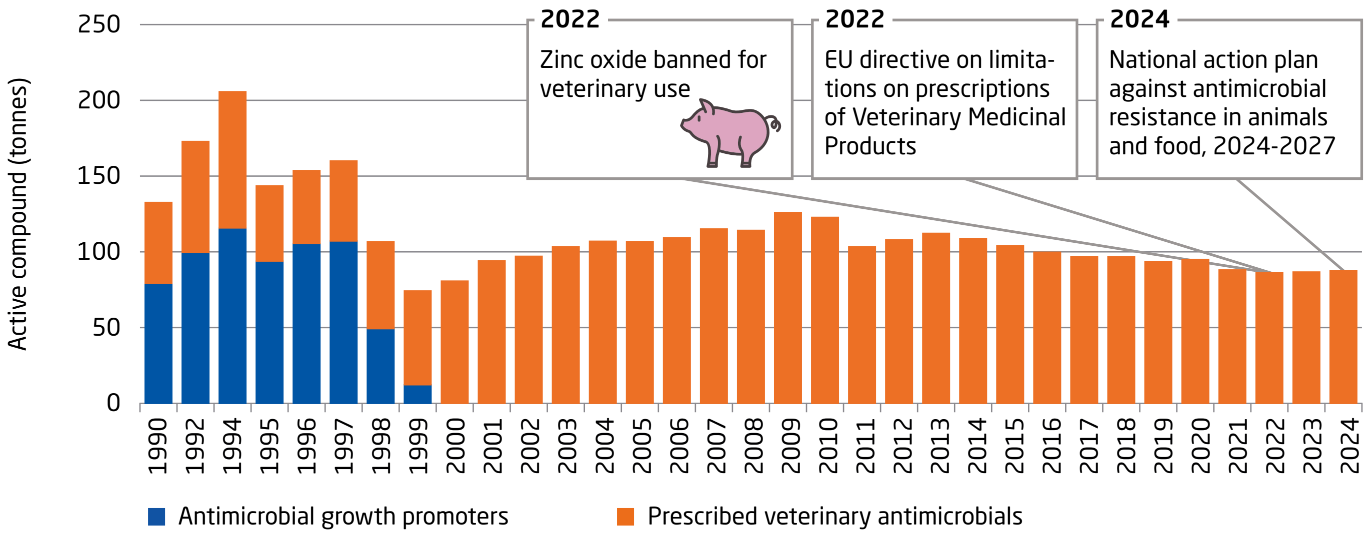
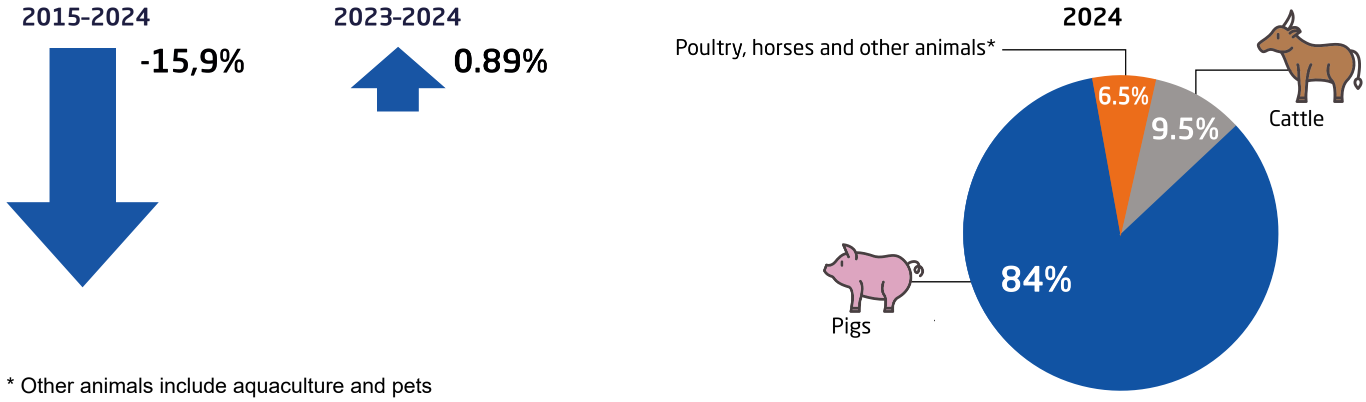
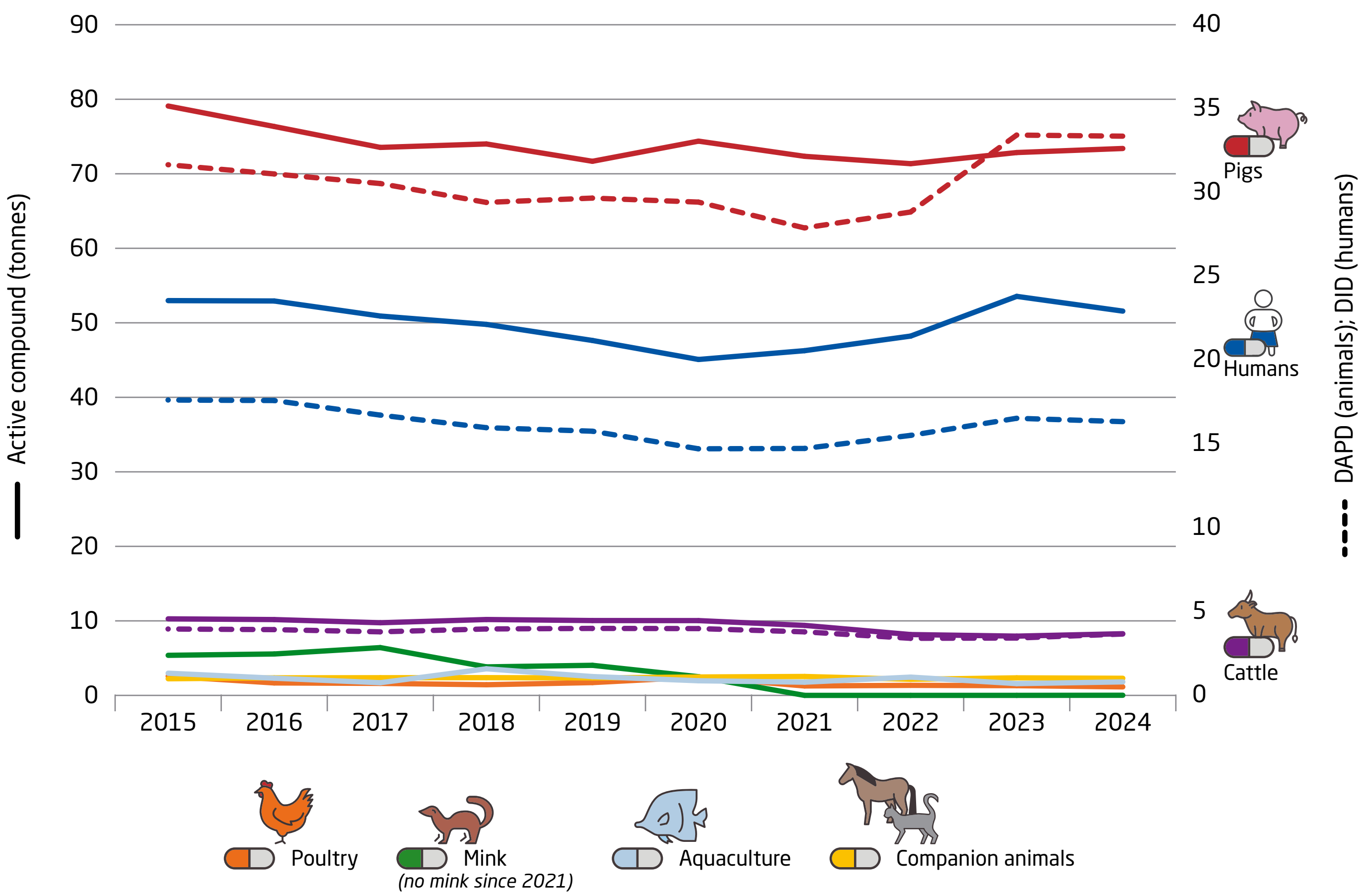


Figure 2.2 Changes in overall antimicrobial consumption and its distribution (%) by main animal species, Denmark



* Other animals include aquaculture and pets

Figure 2.3 Total antimicrobial consumption of active compounds (kg) by animal species and humans, Denmark, 2015-2024



Small amounts of kg active (522.6 kg) compound were used by unspecified animal species in 2024

The overall usage of active antimicrobial compounds in animals declined from 2015 to 2022. However, in 2023 and 2024, consumption gradually increased each year (Figure 2.1). In 2024, total usage was 15.94% lower compared to 2015, and slightly higher than in 2023, with an increase of less than 1% or 775.60 kilograms (Figure 2.2). Species-specific data for 2024 show that consumption measured as kg active compound decreased in poultry and companion animals, while usage increased in pigs, cattle, and aquaculture (Figure 2.3).

The pig sector remains the primary contributor to veterinary antimicrobial consumption in Denmark. Consequently, any significant shifts in usage patterns within this sector have a substantial influence on overall antimicrobial consumption in animals. In 2024, pigs accounted for approximately 84% of all veterinary-prescribed antimicrobials, corresponding to 73.40 tonnes of active compounds (Figure 2.3).

For the DANMAP 2024 report, the DADD values were revised for both pigs and cattle, leading to notable changes in the calculated treatment proportions, particularly for the substances neomycin and procaine benzylpenicillin. These adjustments have had a measurable impact on the calculation of DAPD, which is used to assess treatment proportions across animal populations. The revision has influenced the overall DAPD values for the antimicrobial classes aminoglycosides and beta-lactamase-sensitive penicillins, where the updated DADD values have resulted in shifts in the apparent treatment proportions (DAPD).

Antimicrobial consumption in pigs

Animal definitions

Antimicrobial consumption varies across age groups within the pig population, with weaners accounting for a particularly high share. In DANMAP, data are reported both collectively and separately for three distinct age groups: **sows/piglets**, **weaners**, and **finishers**.

Sow: Any breeding female pig.

Piglet: A newborn pig is referred to as a piglet from birth until it is weaned typically at 3 to 4 weeks of age. At the time of weaning, a piglet weighs approximately 7 kg.

Weaner: A pig weighing between 7 and 30 kg, following weaning.

Finisher: A pig weighing between 30 and 100 kg, from the end of the weaner stage until slaughter.

In 2024, the total consumption of antimicrobials in **pigs** reached 73.40 tonnes, reflecting an increase of 0.54 tonnes of active compound compared to 2023 (Figures 2.3 and 2.4). At the age group level, usage increased by 192.60 kg in sows and piglets and by 930.20 kg in weaners, while a reduction of 579.14 kg was observed in finishers. This shift in usage patterns coincided with a 0.48% increase in total pig biomass. The increase was primarily driven by a higher number of weaners and a reduction in the number of finishers, which likely influenced the distribution of antimicrobial treatments across production stages.

Changes in antimicrobial consumption for pigs driven by the Yellow Card initiatives

Several initiatives under the Yellow Card scheme have focused on reducing antimicrobial use in pigs, with particular emphasis on tetracyclines due to their potential to select for livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA). In parallel, efforts have also focused on phasing out antimicrobials critical for human treatment classified as "Watch" or "Reserve" (see Chapter 3), including fluoroquinolones, cephalosporins, and colistin. For a historical overview of the changes in antimicrobial use across different pig age groups please refer to the DANMAP 2024 report.

The Yellow Card Initiative

In 2010, the Danish Veterinary and Food Administration (DVFA) introduced the Yellow Card initiative to reduce the use of antimicrobials in Danish pig production. The initiative targets farms with high levels of antimicrobial consumption and serves as an incentive for producers to contribute to national reduction goals.

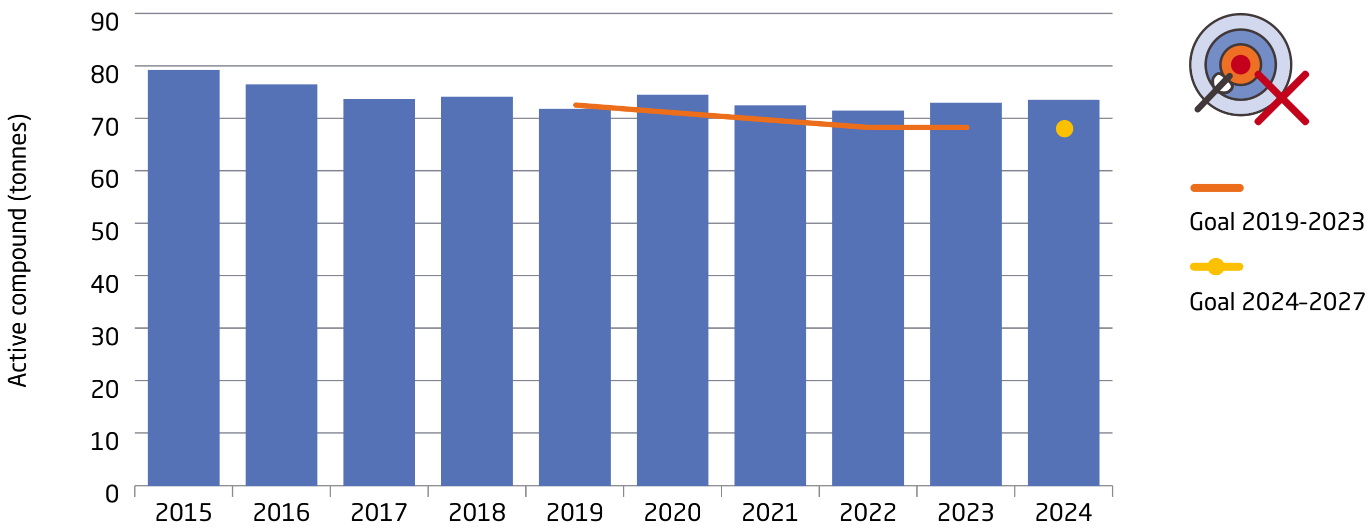
The system is based on detailed monitoring of antimicrobial consumption at the individual farm level. If the average consumption on a holding exceeds the threshold level within a nine-month period, with the threshold individually calculated based on the farm's production size, the DVFA may issue an order or injunction, known as a "yellow card." This compels the farm owner to reduce antimicrobial use to below the threshold within nine months of receiving the injunction.

In 2016, the initiative was further developed with the introduction of multiplication factors to adjust the weighting of specific antimicrobial agents. These factors, determined by the DVFA, serve as risk mitigation tools for each antimicrobial class. Fluoroquinolones and cephalosporins, which are considered critically important for human medicine, were assigned the highest multiplication factor of 10. Tetracyclines received a factor of 1.5 to encourage further reductions in their use, and colistin was also given a factor of 10 as a precautionary measure.

The differentiated Yellow Card system has proven to be a useful tool for reducing overall antimicrobial use in pig herds and discouraging the use of critically important antimicrobials. For more information, see DANMAP 2010 or visit www.fvst.dk.

The combined implementation of the National Action Plan and the Yellow Card initiative constitutes a strategic framework for reducing antimicrobial usage in pig production. Nevertheless, the National Action Plan´s reduction target established in 2019 was not met in 2023, indicating persistent challenges in achieving sustained decreases in the usage of antimicrobials. The revised National Action Plan 2024 may act as a regulatory driver for achieving the targeted 8% reduction in antimicrobial consumption by 2027 (Figure 2.4).

Figure 2.4 Antimicrobial consumption in pigs in relation to national goals for reducing usage of antibiotics in pigs, Denmark, 2015-2024



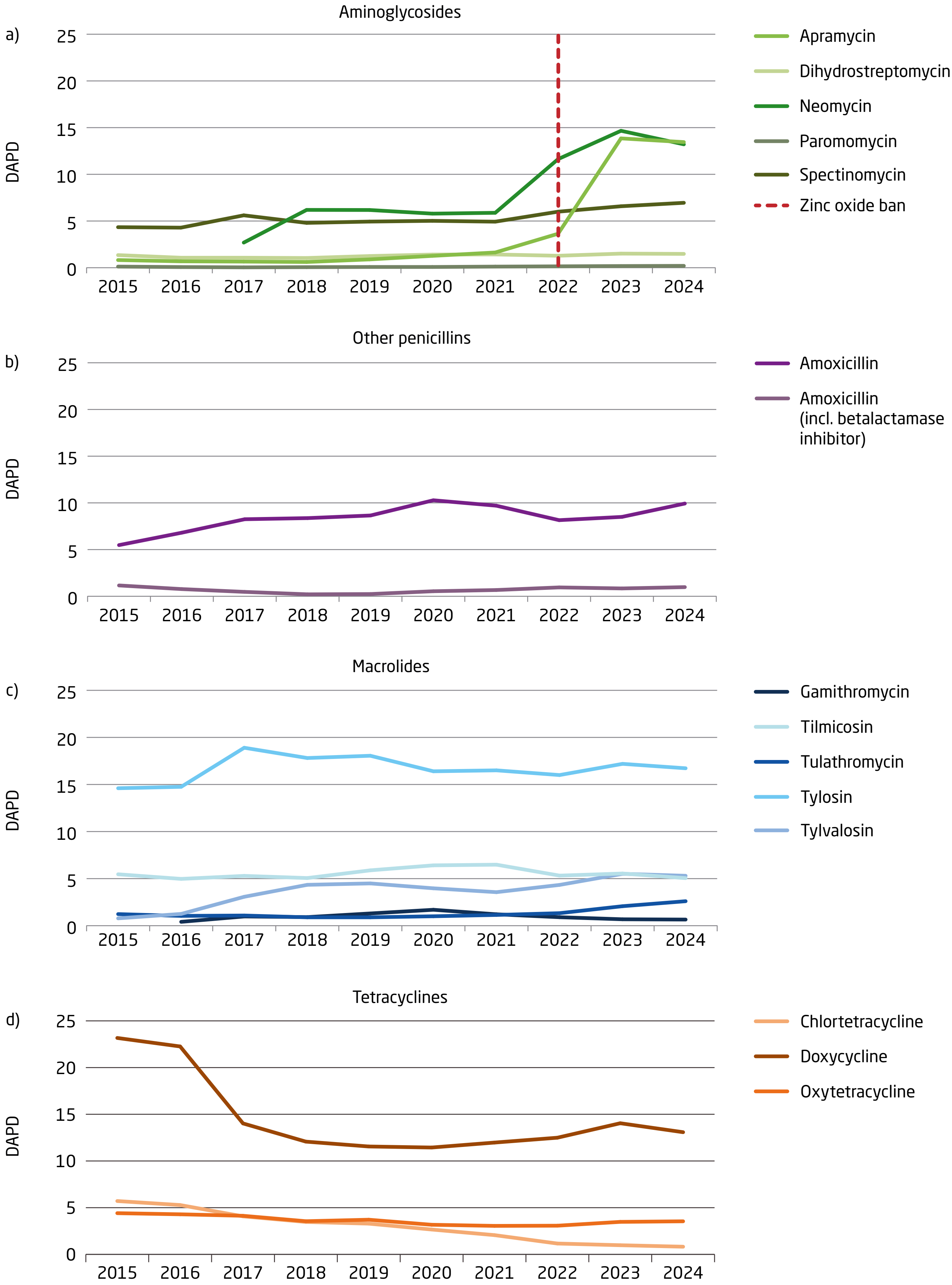
Measured as treatment proportion (DAPD), which accounts for changes in biomass, an estimated 3.3% (33.3 DAPD) of the pig population received antimicrobial treatment per day in 2024, representing a slight decrease of 0.2% compared to 2023. In 2010, when the Yellow Card initiative was introduced, the daily treatment proportion was approximately 3.7%.

At the age-group level, the distribution of antimicrobial treatment varies considerably. On a given day in 2024, approximately 1–2% of sows and piglets and finishers, received treatment, whereas 11.6% of weaners were treated with antimicrobials. Over time, the treatment proportion has consistently been substantially higher in weaners compared to other age groups, reflecting differences in disease susceptibility, management practices, and production dynamics. In 2024, antimicrobial usage in weaners, measured as DAPD, decreased by 2.0% compared to 2023 (Figure 2.5). This reduction was primarily driven by decreased usage of aminoglycosides, macrolides, and tetracyclines (Figure 2.5 a. and c-d.). Conversely, an increase in the usage of other penicillins was observed during the same period (Figure 2.5 b.).

The elevated usage of aminoglycosides between 2021 and 2023 coincided with the European Commission's withdrawal of medical zinc oxide for pigs, effective from June 2022. Zinc oxide had previously been widely administered to newly weaned pigs to prevent or manage post-weaning diarrhea. Its removal likely led to a temporary shift toward alternative antimicrobial treatments, including aminoglycosides. By 2024, however, aminoglycoside usage had declined by 4.1%, indicating a subsequent adjustment in treatment strategies following the initial response to the zinc oxide ban.

Lastly, the previously discontinued use of colistin, along with the implementation of Regulation (EU) 2019/6 on veterinary medicinal products, effective from January 2022, may have influenced patterns of antimicrobial usage. Furthermore, structural changes in pig production, specifically the increased export of 30 kg pigs and the concurrent decline in the number of pigs slaughtered domestically, could also have contributed to the observed shifts in antimicrobial consumption.

Figure 2.5 Consumption (DAPD) of aminoglycosides, macrolides and tetracyclines at active compound level in weaners, Denmark, 2015-2024

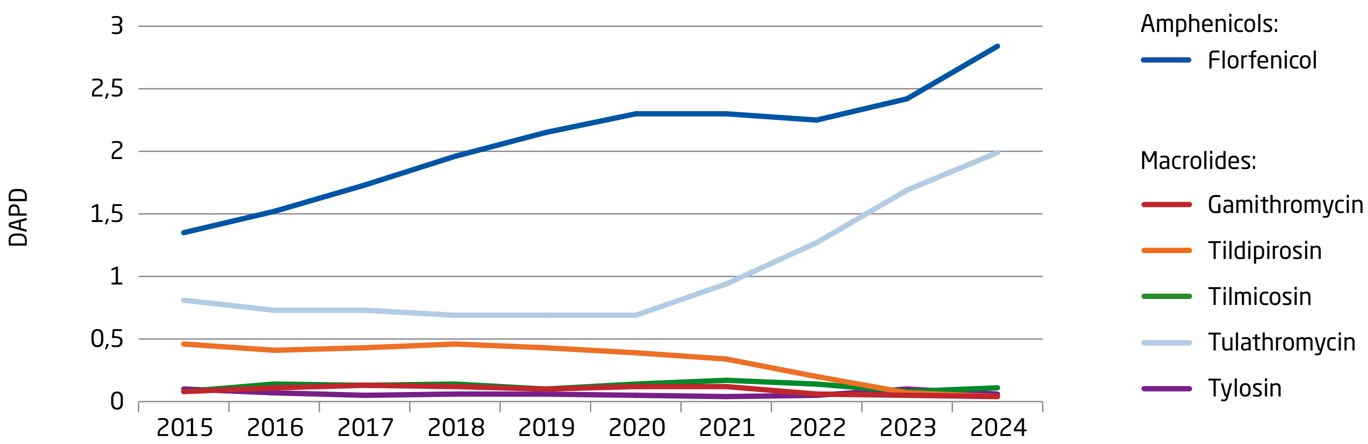


Antimicrobial consumption in cattle

In 2024, the total consumption of antimicrobials in **cattle** was 8.28 tonnes, representing an increase of 324.15 kg of active compound compared to 2023 (Figures 2.3). At the age group level, usage increased by 213.78 kg in adult cattle, primarily for systemic treatments, and by 110.37 kg in calves. During the same period, the overall biomass of cattle declined by 1.80%. This decrease was observed in both adult cattle and calves, suggesting that the increase in antimicrobial consumption cannot be attributed to a larger population. Antimicrobial usage in cattle has generally declined over the past decade. In 2024, consumption was 19.42% lower than in 2015. However, a 4.08% increase compared to 2023 indicates a recent deviation from the long-term downward trend.

Measured as DAPD, which adjusts for changes in biomass, an estimated 0.36% (3.60 DAPD) of the cattle population received antimicrobial treatment on any given day in 2024. This is an increase of 7.11% compared to 2023. At the age group level, the DAPD varied considerably. On a given day in 2024, approximately 0.27% of adult cattle received treatment, whereas 0.81% of calves were treated with antimicrobials. Over time, DAPD values have consistently been higher in calves than in adult cattle, reflecting differences in disease susceptibility, management practices, and production dynamics. In 2024, antimicrobial usage in calves, measured as DAPD, increased by 8.75% compared to 2023. The increase was primarily driven by elevated usage of amphenicols (florfenicol) and macrolides (Figure 2.6).

Figure 2.6 Consumption (DAPD) of amphenicols and macrolides at active compound level in cattle <1 year, Denmark, 2015-2024



Antimicrobial consumption in other food-producing animals

Antimicrobial usage in Danish **poultry** remains generally low. Consequently, national statistics can be significantly influenced by disease outbreaks on just a few farms. In 2024, antimicrobial consumption decreased by 12.63% compared to 2023 (Figure 2.4). Importantly, cephalosporins have not been used in the poultry sector for over a decade, and fluoroquinolones have not been used since 2019.

In **aquaculture**, antimicrobial consumption varies considerably depending on water temperature, as bacterial infections tend to occur more frequently during warmer periods. In 2024, total usage amounted to 1,832.0 kg, representing a 14.64% increase compared to 2023 (Figure 2.4). In aquaculture, the treatment of bacterial diseases primarily relies on three groups of compounds: sulfonamides and trimethoprim (74.6%), other quinolones such as oxolinic acid (17.5%), and amphenicols like florfenicol (7.9%).

Antimicrobial consumption in companion animals

Compared to food-producing animals, data on antimicrobial usage in **companion animals** is less detailed, as species-specific registration is not mandatory. In 2024, consumption was estimated at 2,296.4 kg, which is 2.63% lower than in 2023. Companion animals accounted for more than half of all cephalosporins used, including all third- and fourth-generation generation cephalosporins, and nearly all fluoroquinolones prescribed for veterinary purposes.

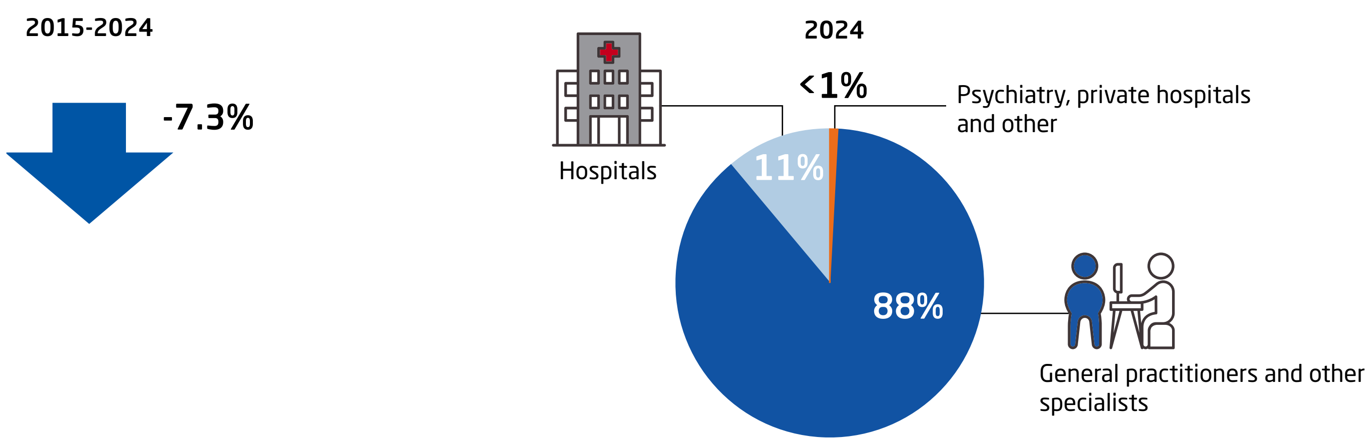
3. Antimicrobial consumption in humans

Surveillance of antimicrobial consumption in humans is based on sales data from all public and private healthcare providers in Denmark. In the following sections, antimicrobial consumption data are presented at national level as well as at health care sector level, i.e. primary health care and hospital care.

Antimicrobials in Denmark

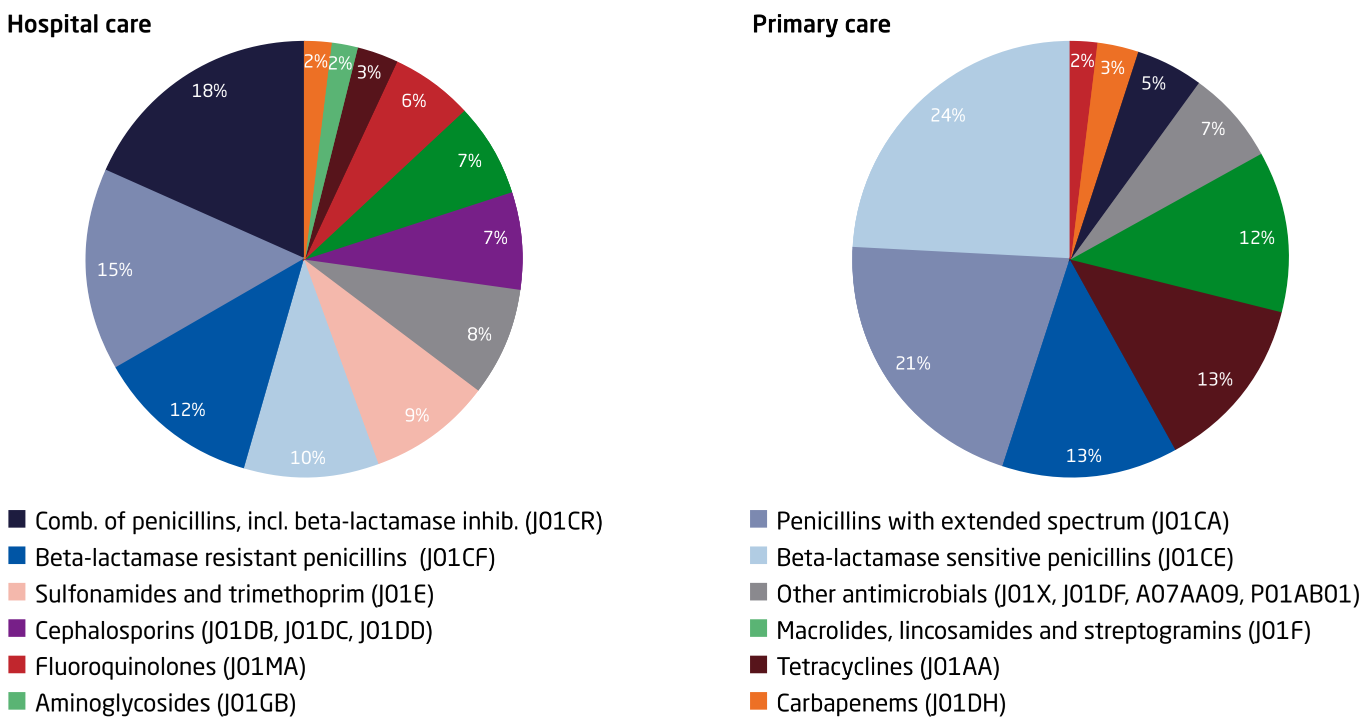
Antimicrobial consumption in Denmark was 16.27 DID in 2024, which is 7.3% lower than consumption in 2015 (17.55 DID) and almost similar to 2023 (16.47 DID). Changes in the total consumption were driven by changes in antimicrobial prescribing in primary care, which accounts for 88% of antibiotics used in Denmark, Figure 3.1.

Figure 3.1 Change in total antimicrobial consumption and distribution by healthcare providers, Denmark, 2015-2024



Penicillins are the main drug classes in Denmark, in primary health care they account for 64% and at hospitals for 55% (Figure 3.2). Hospitals prescribe the majority of broad spectrum and critically important antimicrobials (cephalosporins and carbapenems). Assessed by WHO's AWaRe classification system, "access antimicrobials" constituted 82% of consumption in Denmark in 2024.

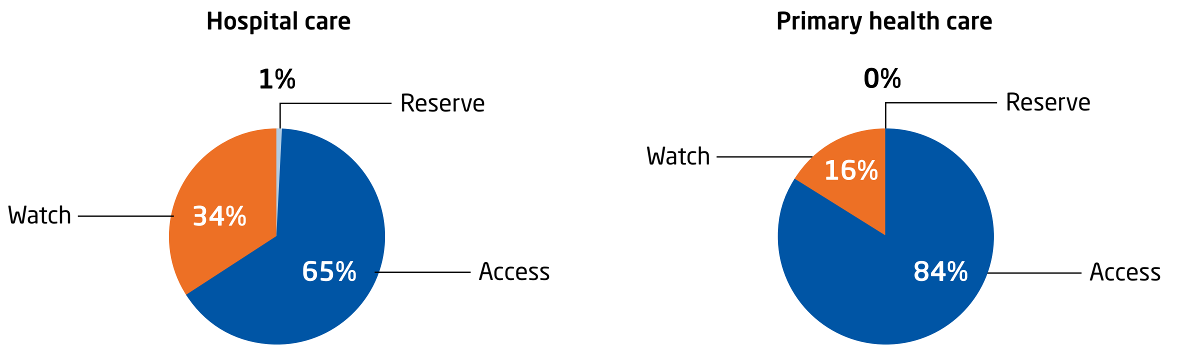
Figure 3.2 Percentage distribution of antimicrobial agents in primary health care and hospital care, DDD, Denmark, 2024



AWaRe classification of antimicrobials in Denmark, 2024

The World Health Organization (WHO) has developed the AWaRe classification system as a tool to assist antibiotic stewardship and to reduce antimicrobial resistance. Antibiotics are classified into three groups to emphasise the importance of their appropriate use:

- **Access:** Antibiotics used to treat common susceptible pathogens with lower resistance potential than antibiotics in the other groups. 60% of total antimicrobial consumption should consist of Access agents.
- **Watch:** Antibiotics that have higher resistance potential, including most of the highest priority agents. These antibiotics should be prioritised as key targets of stewardship programs and monitoring.
- **Reserve:** Antibiotics reserved for treatment of confirmed or suspected infections due to multidrug resistant organisms. These antibiotics should be considered as "last resort" options.

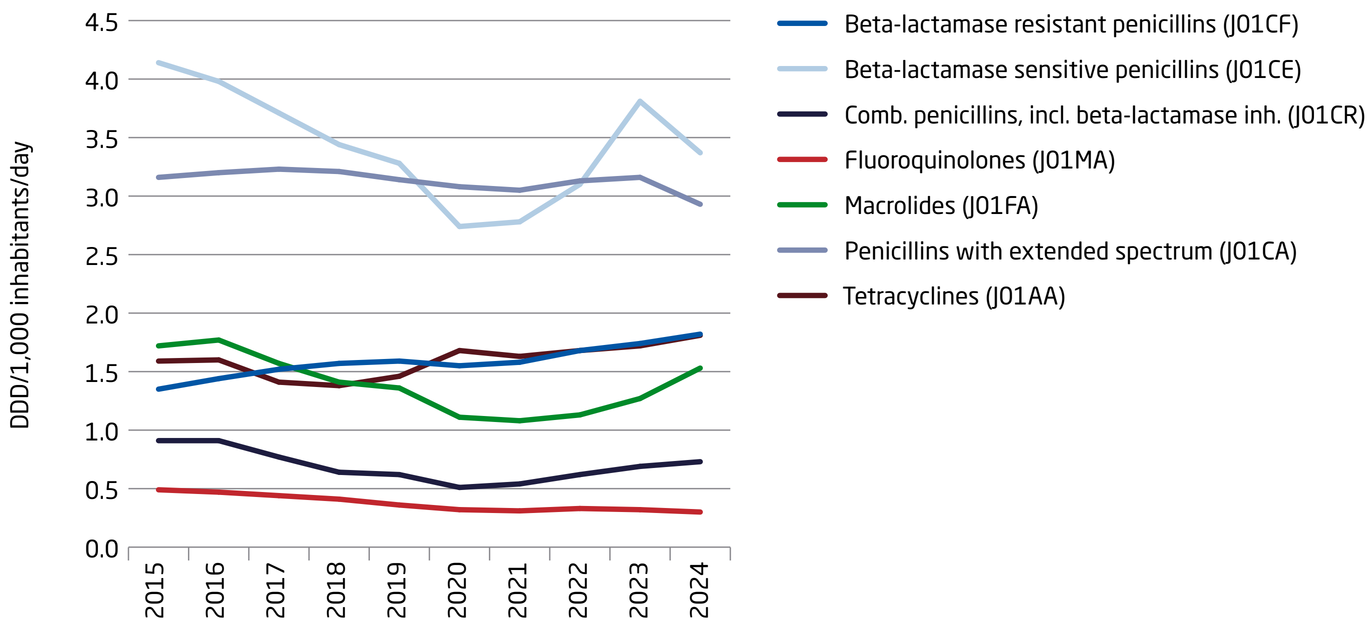


WHO Access, Watch, Reserve (AWaRe) classification of antibiotics for evaluation and monitoring of use, 2017. Geneva: World Health Organization; updated 2023 (WHO-MHP-HPS-EML-2023.04)

Antimicrobials in primary health care

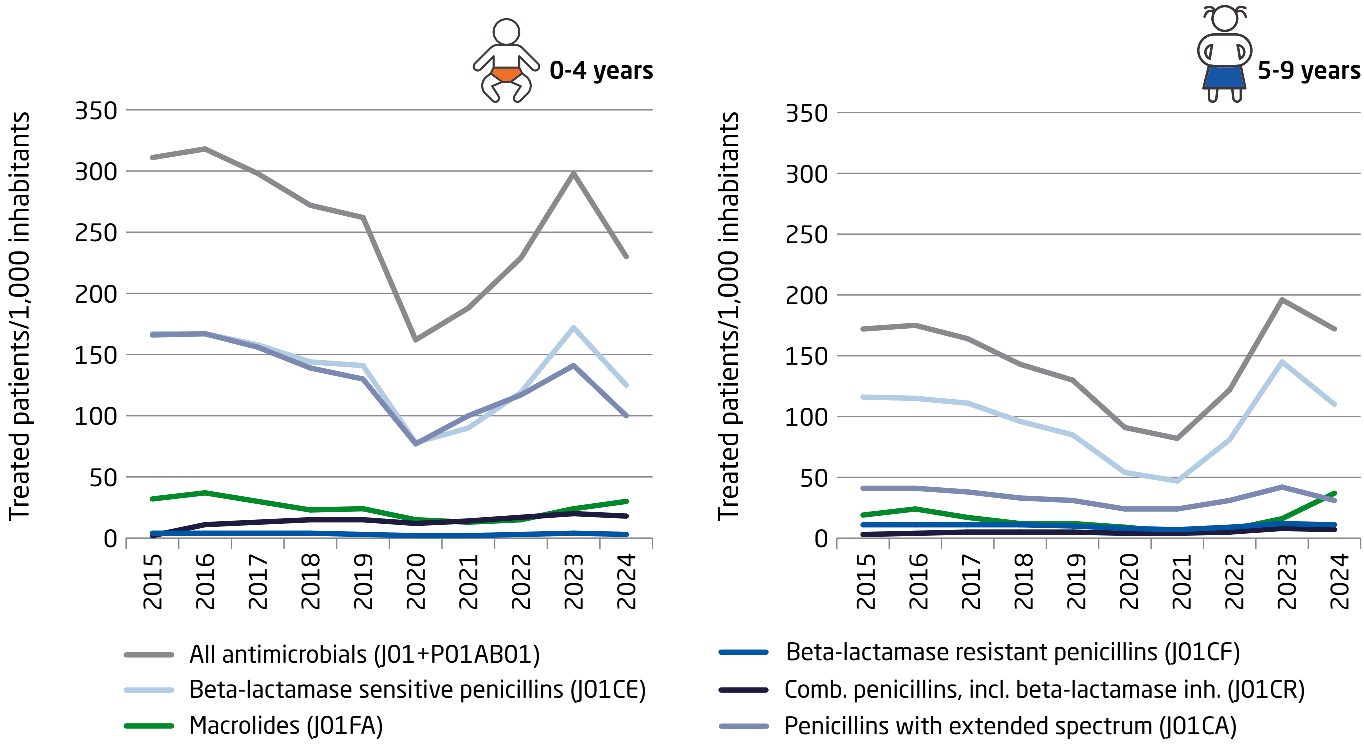
The COVID-19 related increase in cumsption of beta-lactamase sensitive penicillins discontinued in 2024 (-11.6% from 2023 to 2024) probably due renormalized circulation of airway (Figure 3.3). However, beta-lactamase sensitive penicillins was still the largest antimicrobial group in primary health care in Denmark, accounting for 24% in 2024, which is in line with Danish treatment guidelines.

Figure 3.3 Consumption of leading antimicrobial groups for systemic use in primary health care, DDD per 1,000 inhabitants per day, Denmark, 2015-2024



On the other hand, consumption of macrolides increased by 21% from 2023 to 2024, probably due to the Group A streptococcal pandemic in 2023 and 2024, mainly among children and their parents. Among children, the decrease in consumption of beta-lactamase sensitive penicillins (up to 23%) and the increase in macrolide consumption (up to four times) are illustrated in Figure 3.4.

Figure 3.4 Consumption of main antimicrobial agents among children, treated patients/1,000 inhabitants, Denmark, 2015-2024



For the elderly, the consumption has been decreasing since 2016, with steeper decreases observed among elderly living at care homes. However, in 2024 the decreasing trend in consumption discontinued, and the consumption was unchanged for the first time when comparing to the previous year of 2023 (Figure 3.5). Elderly inhabitants living at care homes received 93% more antimicrobials than elderly inhabitants living in their own homes in 2024. Urinary tract infections were the main driver of the difference observed in treatment frequency based on residential status (1116 versus 459 prescriptions for urinary tract infections per 1,000 elderly inhabitants in 2024).

Figure 3.5 Consumption of antimicrobials (J01 and P01AB01) in primary health care for elderly inhabitants living in long term care facilities and for elderly inhabitants living in their own homes, Denmark, 2016-2024

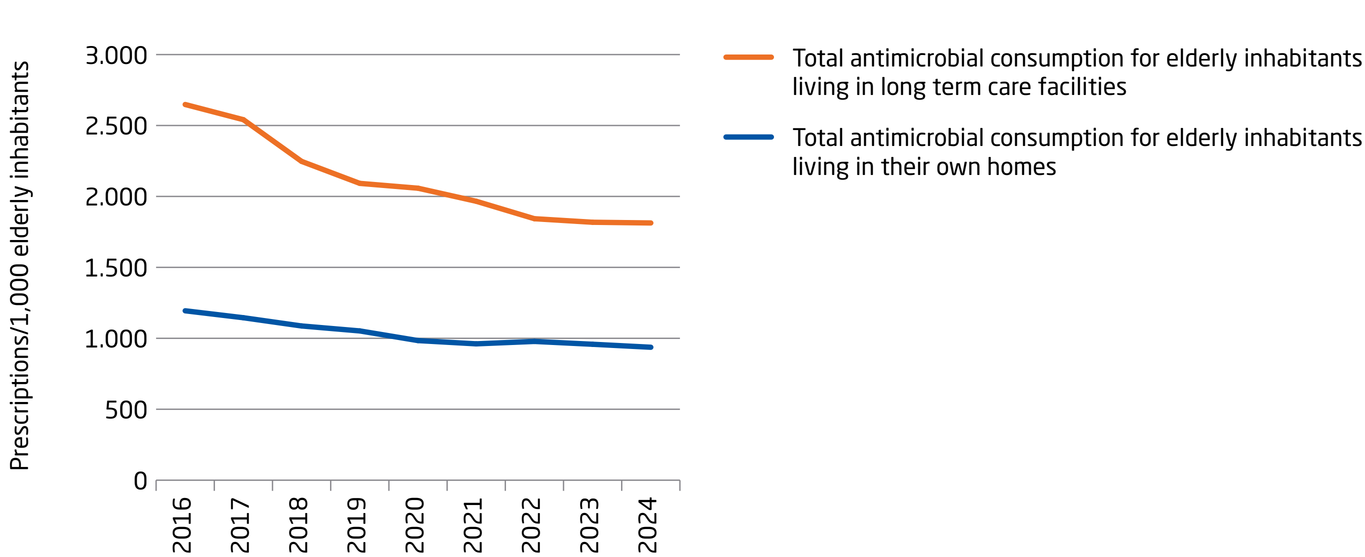
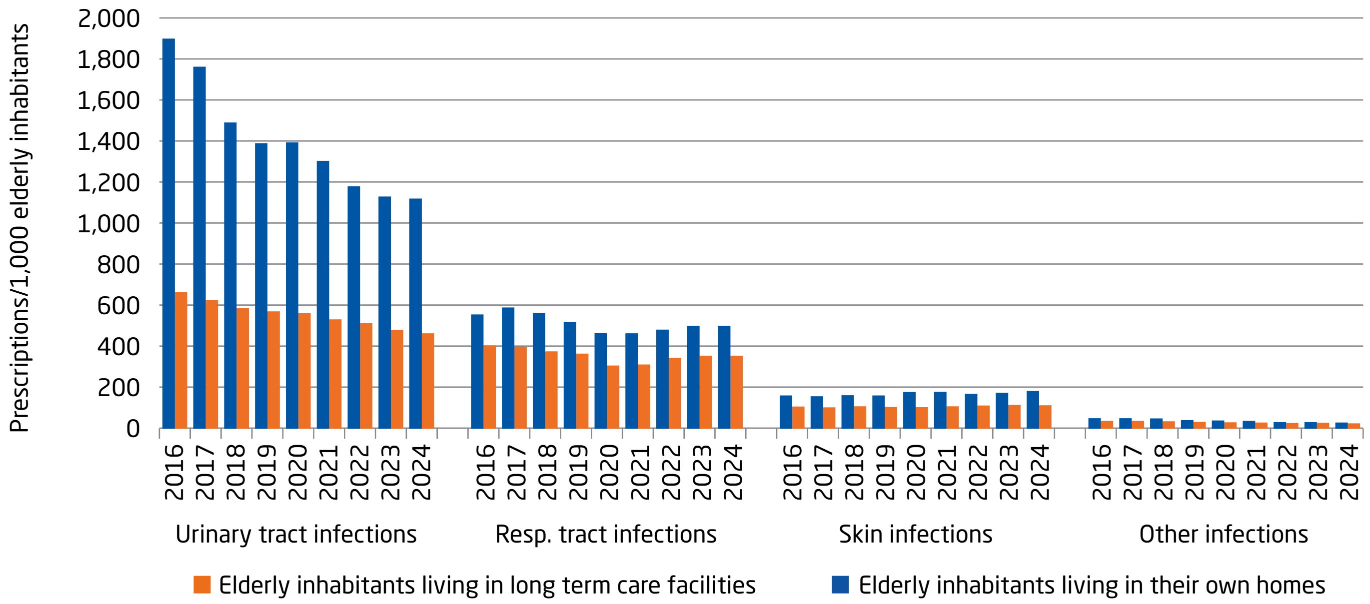


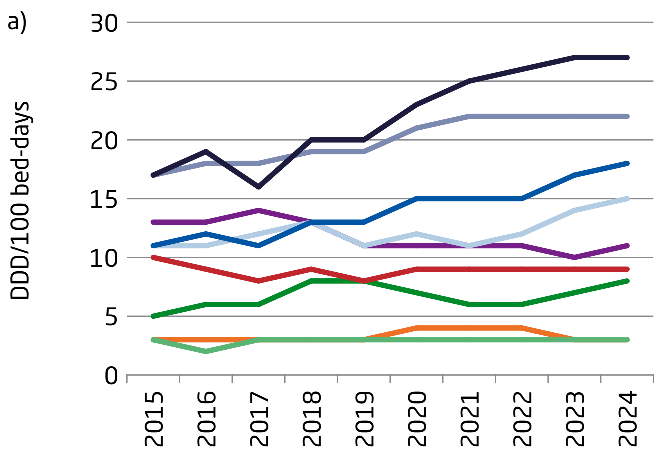
Figure 3.6 Treatment of infections in primary health care for inhabitants ≥65 years, Denmark, 2016-2024

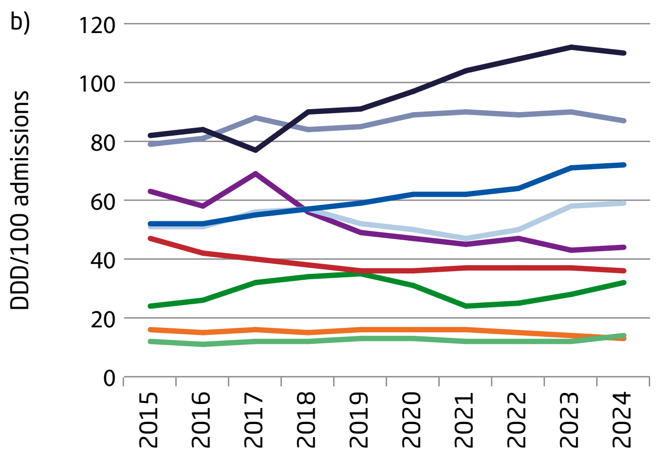


Antimicrobials in hospital care

In hospital care, antimicrobial consumption in 2024 was similar to 2023 after several years with increasing trends when measuring in DDD per 100 bed-days or admissions (Figure 3.7). In particular, combinations of penicillins, including beta-lactamase inhibitors has shown steep increases in recent years but was 2-3% lower in 2024 compared to 2023. Simultaneously, consumption of beta-lactamase sensitive penicillins has increased by 20% since 2022 (DDD per 100 bed-days).

Figure 3.7 Antimicrobial consumption at somatic hospitals by antimicrobial group, a) DDD per 100 bed-days and b) DDD per 100 admissions, Denmark, 2015-2024





Over the last decade consumption of critically important antimicrobials (cephalosporins, carbapenems and fluoroquinolones) has decreased continuously and by 13% in 2024. This reflects the long-standing efforts in everyday clinical practice to keep the consumption low. Also, the national action plan on antimicrobials in human healthcare published in 2017 presented a goal fof 10% decrease in consumption of critically important antimicrobials and the recent action plan published in June 2025 further encourages the positive development.

4. Resistance in zoonotic bacteria

Monitoring results of the occurrence of antimicrobial resistance (AMR) in *Campylobacter* and *Salmonella* in animals and meat can be accessed and interactively visualized in the DANMAP explorer, available at www.DANMAP.org.

Campylobacter spp. are commonly associated with intestinal disease in humans. In Denmark, *C. jejuni* is the dominating pathogenic species, accounting for approximately 90% of the human cases, followed by *C. coli*. Both species are ubiquitous in food-producing animals. However, *C. jejuni* is most commonly found in broilers and cattle, while *C. coli* in pigs. *Salmonella* spp. is also commonly associated with intestinal disease in humans and includes many different serotypes. There is often a correlation between *Salmonella* serotypes and resistance levels, making it difficult to compare these across serotypes. DANMAP focuses on *S.* Typhimurium and monophasic *S.* Typhimurium as these serotypes are present in clinical human isolates and isolates from food-producing animals, especially pigs.

In Denmark, antimicrobials are generally not recommended for treating human patients with diarrhea apart from prolonged or severe cases. When necessary, macrolides (azithromycin) may be used for *Campylobacter* infections. In cases of prolonged or recurrent *Salmonella* infection, treatment with ciprofloxacin or trimethoprim-sulfamethoxazole may be considered, based on antimicrobial susceptibility testing. Information regarding antimicrobial usage for diarrhea at the patient level is currently not available.

In Danish animal production, macrolides are often used to treat infections in pigs, while the use of antimicrobials in poultry is low and primarily limited to tetracyclines.

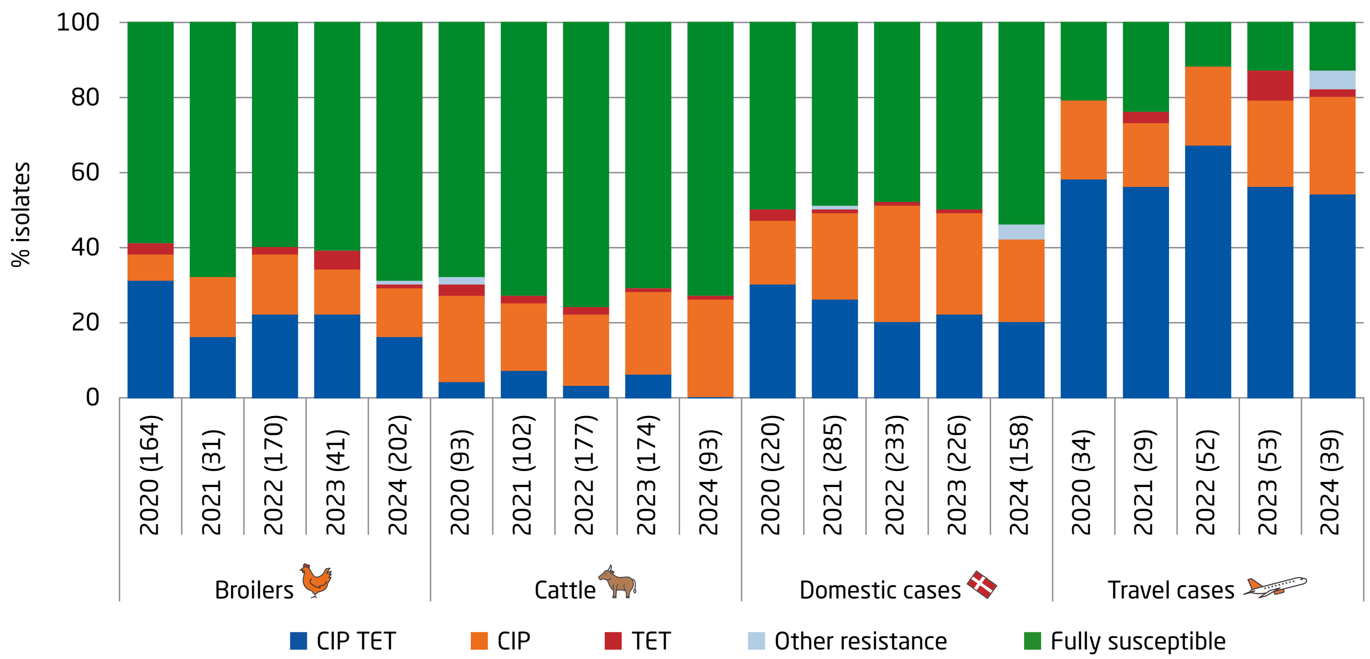
Resistance in *Campylobacter jejuni*

Resistance levels in human *C. jejuni* isolates were comparable to those observed in previous years, with travel-associated cases showing higher resistance levels than domestically acquired cases (Figure 4.1). Resistance levels in *C. jejuni* from broilers and cattle remained stable over time and were lower than those observed in human isolates (Figure 4.1).

Combined resistance to ciprofloxacin and tetracycline remained common in human and broiler isolates

In human *C. jejuni* isolates, combined resistance to ciprofloxacin and tetracycline was observed in 54% of travel-related cases and 20% of domestically acquired cases (Figure 4.1). Combined resistance to ciprofloxacin and tetracycline was lower in *C. jejuni* from broilers (16%) and was not detected in cattle (Figure 4.1)

Figure 4.1 Distribution (%) of AMR profiles among *Campylobacter jejuni* from broilers, cattle and human cases, Denmark, 2020-2024



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

Resistance to macrolides and carbapenems remained low

Macrolide (erythromycin) resistance remained rare in *C. jejuni* from cattle and was not observed in isolates from humans and broilers. Carbapenem (ertapenem) resistance remained low in isolates from boilers (7%) and was not detected in cattle.

Resistance in *Campylobacter coli*

Resistance levels in *C. coli* from human and broiler isolates were overall higher than those observed in *C. jejuni*.

> Resistance to erythromycin was observed in 14% of the human isolates and in 17% of isolates from broilers. This is an important finding as macrolides are used for the treatment of severely ill human patients.

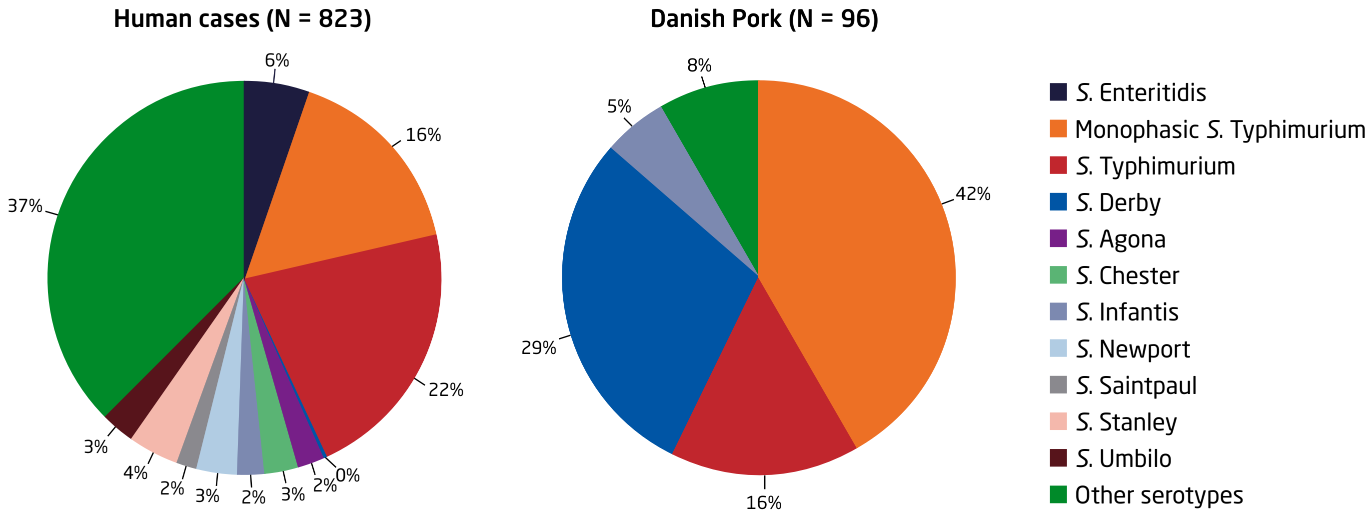
Overall, the comparably high levels of resistance in *C. coli* from human and broiler isolates suggest that broilers could be a probable source of infection with *C. coli* in humans. In DANMAP 2023, *C. coli* isolates from pigs showed lower resistance levels than those observed in 2024 in human and broiler isolates.

Resistance in *Salmonella* spp.

In 2024, a total of 823 human clinical *Salmonella* spp. isolates, representing 102 different serotypes, were tested for antimicrobial susceptibility. The predominant serotypes were *S.* Typhimurium (178), monophasic *S.* Typhimurium with the antigenic formula 4,[5], 12:i:- (133), and *S.* Enteritidis (44). Except for *S.* Enteritidis, the tested isolates represented all clinical Danish isolates and included outbreak isolates.

Also, in 2024, a total of 96 *Salmonella* spp. isolates from domestic pork were tested for antimicrobial susceptibility. The most common serotypes reported in pork were monophasic *S.* Typhimurium with the antigenic formula 4,[5], 12:i:- (40), *S.* Derby (28), and *S.* Typhimurium (15).

Figure 4.2 Distribution (%) of *Salmonella* serotypes from Danish pork and human cases included in DANMAP, 2024



In addition to results from phenotypic resistance testing, DANMAP 2024 presents results from whole-genome sequencing of 466 *S.* Typhimurium and 408 monophasic *S.* Typhimurium isolates obtained from human cases between 2020 and 2024. Similarly, results are presented for 57 *S.* Typhimurium and 145 monophasic *S.* Typhimurium isolates from Danish pork collected during the same period.

DANMAP 2024 only presents data from human clinical isolates and domestic pork isolates. The lack of AMR results from isolates originating from a wider variety of food and animal sources limits the options to compare resistance levels between human cases and relevant sources other than pork. It is well established that Danish pork is only one of several sources of human salmonellosis. To gain a better understanding of the clonal dissemination contributing to the spread of AMR, particularly among *S.* Typhimurium and its monophasic variant, *Salmonella* sources other than Danish pork could be monitored. The results of the susceptibility testing of *Salmonella* isolates are presented in Table 4.1.

Table 4.1. Resistance (%) in *Salmonella* spp., *S.* Typhimurium and monophasic *S.* Typhimurium isolates from Danish pork and humans, Denmark, 2024

	S. Typhimurium	Monophasic *S.* Typhimurium	*S.* Typhimurium		Monophasic *S.* Typhimurium		Other *Salmonella* serotypes	
	Pork		Human					
	Danish	Danish	Domestically acquired	Travel abroad reported	Domestically acquired	Travel abroad reported	Domestically acquired	Travel abroad reported
Antimicrobial agent	%	%	%	%	%	%	%	%
Amikacin	0	3	0	0	0	0	0	0
Ampicillin	80	80	12	22	39	81	5	12
Azithromycin	0	5	0	0	1	14	2	1
Cefotaxime	0	0	0	0	2	10	2	3
Ceftazidime	0	0	0	0	2	10	2	3
Chloramphenicol	47	5	10	22	6	29	4	4
Ciprofloxacin	0	0	2	26	2	33	8	22
Colistin	0	0	1	0	1	10	2	3
Gentamicin	20	8	0	0	1	5	0	0
Meropenem	0	0	0	0	0	0	0	0
Nalidixic acid	0	0	2	19	3	33	7	19
Sulfamethoxazole	73	85	69	44	35	71	5	7
Tetracycline	47	80	66	44	32	81	10	12
Tigecycline	0	3	10	0	7	5	10	8
Trimethoprim	47	25	2	19	8	38	4	3
Fully susceptible (%)	7	10	27	52	55	10	76	67
Number of isolates	15	40	124	27	88	21	183	233

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 *Salmonella* Typhimurium and monophasic *S.* Typhimurium

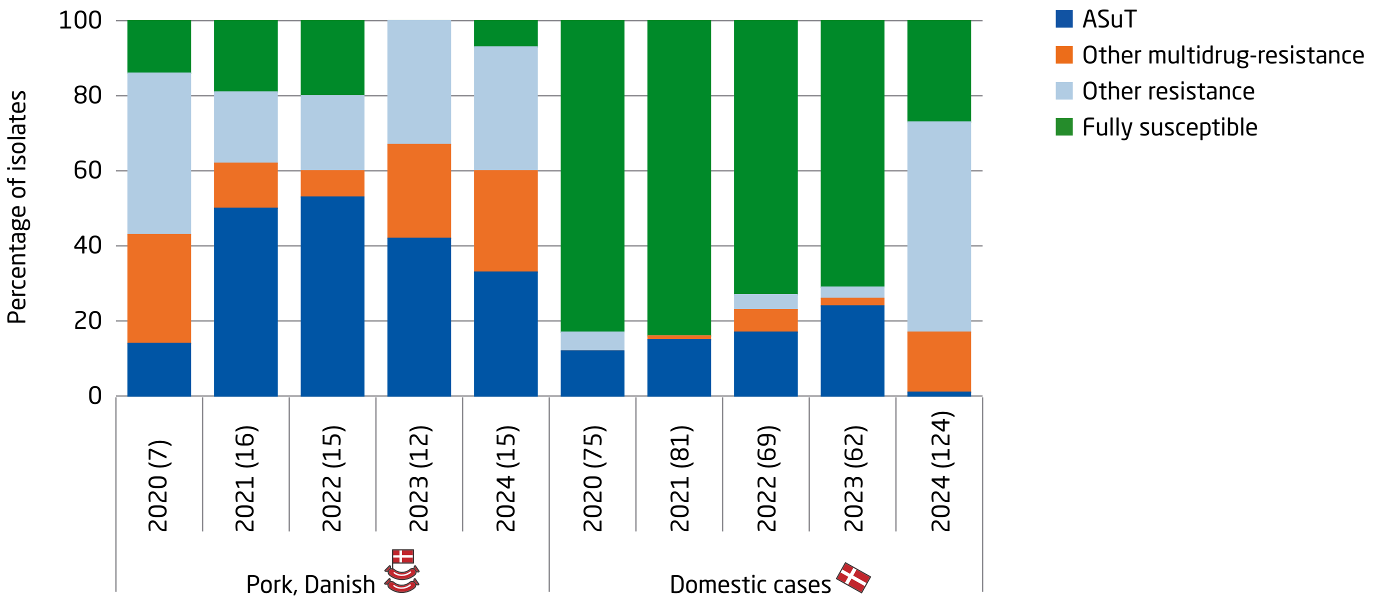
In 2024, two large human outbreaks caused by *S.* Typhimurium and monophasic *S.* Typhimurium affected the overall levels of resistance in human isolates (DANMAP 2024, Figure 4.3). The *S.* Typhimurium outbreak was caused by a clone resistant to sulphonamides and tetracycline with a specific genetic resistance profile *aph(3")-Ib/aph(6)-Id/sul2/tet(A)* and the monophasic *S.* Typhimurium outbreak was caused by an atypical fully susceptible clone. The abundance of outbreak-associated isolates in 2024 makes it difficult to compare the levels of resistance with those from previous years. However, when disregarding outbreak-related isolates, resistance levels and AMR profiles were similar to those observed during 2020-2023.

Among *S.* Typhimurium and monophasic *S.* Typhimurium isolates from pork, the level of full susceptibility increased compared to 2023 (Figure 4.3). Resistance to ampicillin, sulfamethoxazole, and tetracycline (ASuT) remained common in monophasic *S.* Typhimurium isolates from Danish pork (Figure 4.3B). The ASuT multidrug resistance profile was identified in 105 monophasic *S.* Typhimurium isolates between 2020 - 2024, showing similar results from phenotypic and WGS analysis. The most common gene combination was *aph(3")/Ib-aph(6)-Id/aph(3')-Ia/blaTEM-1/sul2/tet(B)*, which was present in 41 isolates.

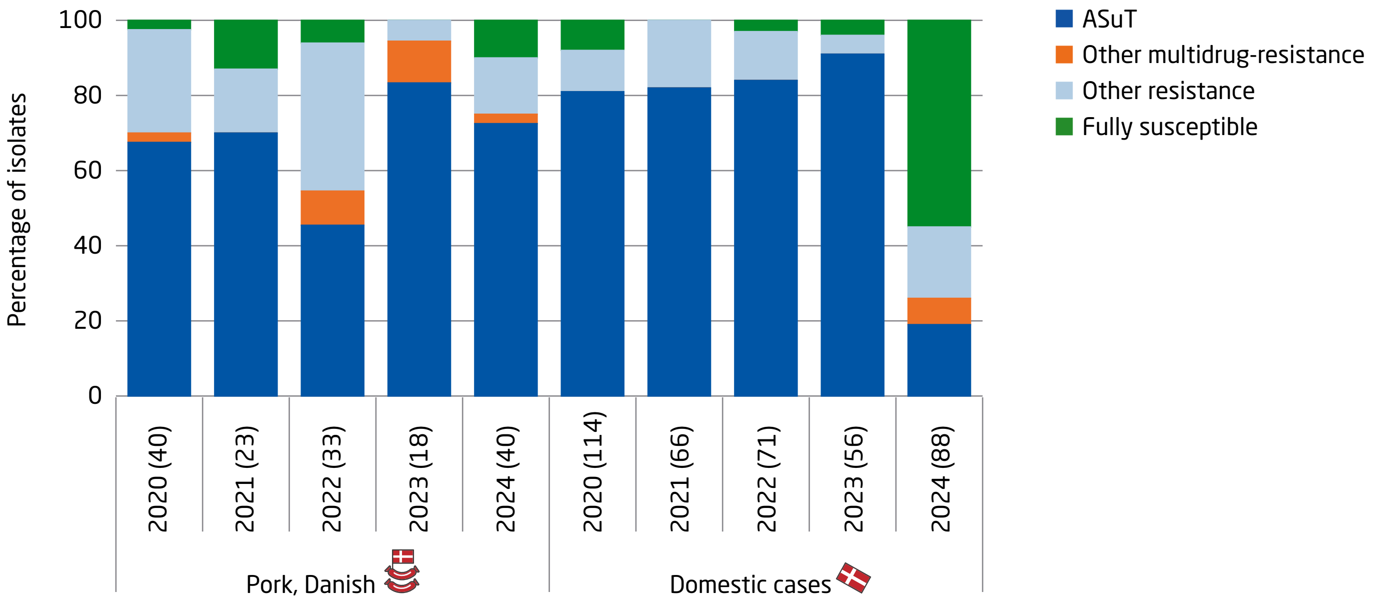
Although less prevalent, the ASuT MDR profile was also commonly found in *S.* Typhimurium isolates from Danish pork (Figure 4.3A). Between 2020 and 2024, this MDR profile was the most frequently detected based on WGS data and was present in 25 pork isolates. However, 16 different gene combinations containing the ASuT profile were found, with *aph(3")-Ib/aph(6)-Id/bla-TEM-1/sul2/tet(A)* as the most common (present in five isolates).

Figure 4.3 Relative distributions (%) of AMR profiles among *Salmonella* Typhimurium (a) and monophasic *S.* Typhimurium (b) from Danish pork and human domestic cases, Denmark, 2020-2024

a) *S.* Typhimurium



b) Monophasic *S.* Typhimurium



Low levels of macrolide, cephalosporin and aminoglycoside resistance
Resistance to macrolides (azithromycin), meropenem, third-generation cephalosporins (cefotaxime and ceftazidime), and aminoglycosides (amikacin and gentamicin) was not observed, or the levels were low in isolates from human cases. Two genetic determinants - *mph(A)* gene and an *acrB* R717 mutation - conferring resistance to azithromycin were identified among the genotypically tested *S.* Typhimurium and monophasic *S.* Typhimurium isolates. With regard to third-generation cephalosporins, four distinct genes (*blaCTX-M-1, blaCTX-M-14, blaCTX-M-55, blaSHV-12*) were detected in monophasic *S.* Typhimurium isolates, while one isolate of *S.* Typhimurium harbored the *blaCMY-2*. For gentamicin, five determinants (*acc(3)-IId, aac(3)-IIe, aac(3)-IVa, aac(3)-IIg, aac(6)-IIc*) were recorded in monophasic *S.* Typhimurium isolates, and two (*aac(3)-IVa, aac(3)-IId*) were detected in *S.* Typhimurium isolates.

In domestic pork isolates, phenotypic resistance levels to gentamicin remained similar to those observed in 2022 and 2023. Among the genotypically tested *S.* Typhimurium and monophasic *S.* Typhimurium between 2020 and 2024, several genes were found that confer resistance to amikacin (*aph(3')-Id*) and gentamicin (*aac(3)-IId and aac(3)-IVa*).

Phenotypic resistance to azithromycin was detected in two monophasic *S.* Typhimurium isolates from Danish pork in 2024. One of these isolates carried the *mph(A)* gene, while the other harbored the *mef(C)-mph(G)* tandem genes. Resistance genes associated with macrolide resistance were rare among the isolates that were genotypically tested from 2020-2024. Both in 2020 and 2023, no resistance genes conferring macrolide resistance were found. While in 2021 and 2022, two monophasic S. Typhimurium isolates carried the *acrB_R717Q/L* substitution.

High diversity of quinolone resistance determinants in human isolates
Phenotypic resistance to fluoroquinolones (ciprofloxacin) was observed in 6% of *S.* Typhimurium isolates, 7% of monophasic *S.* Typhimurium isolates, and 15% of other *Salmonella* serovars. Travel-associated cases showed higher levels of phenotypic resistance across all serovars. Genotypically, a high diversity of quinolone resistance determinants (12) was identified in *S.* Typhimurium and its monophasic variant. Notably, *S.* Typhimurium isolates, particularly from travel-associated cases, exhibited a greater diversity of quinolone resistance determinants than monophasic *S.* Typhimurium isolates.

In domestic pork, ciprofloxacin resistance has remained undetected since 2015.

Six human isolates (1%) were simultaneously resistant to azithromycin, third-generation cephalosporins and ciprofloxacin and thereby resistant towards antimicrobials that are frequently used for empirical treatment of human infections. The infections in the six cases were caused by monophasic *S.* Typhimurium (3), *S.* Muenster (1) and *S.* Saintpaul (2). Three of the six cases were associated with travel, and three cases were acquired domestically.

5. Resistance in indicator bacteria

Monitoring results for occurrence of resistance in indicator *E. coli*, indicator Enterococci and β-lactamase-producing *E. coli* from food-producing animals and meat can be accessed and interactively visualized in DANMAP explorer, available at www.DANMAP.org.

Escherichia coli and Enterococci (*E. faecalis* and *E. faecium*) are included in the DANMAP programme as indicators to monitor trends in the occurrence of antimicrobial resistance in different food-producing animals. In DANMAP, resistance is always monitored in indicator *E. coli* from broilers, pigs and calves at slaughter. In 2024, resistance in *E. faecalis* and *E. faecium* was also monitored in broilers at slaughter.

E. coli exhibiting resistance to beta-lactam antibiotics via production of beta-lactamases, including extended-spectrum β-lactamases (ESBL), cephalosporinases (AmpC) and carbapenemases (CP) are monitored in DANMAP, both via antimicrobial susceptibility testing and whole genome sequencing (WGS). In 2024, ESBL-/AmpC-/CP-producing *E. coli* was monitored with selective enrichment in broilers at slaughter and in broiler and turkey meat at retail. As in previous years, there was no detection of CP-producing *E. coli* (including OXA-48).

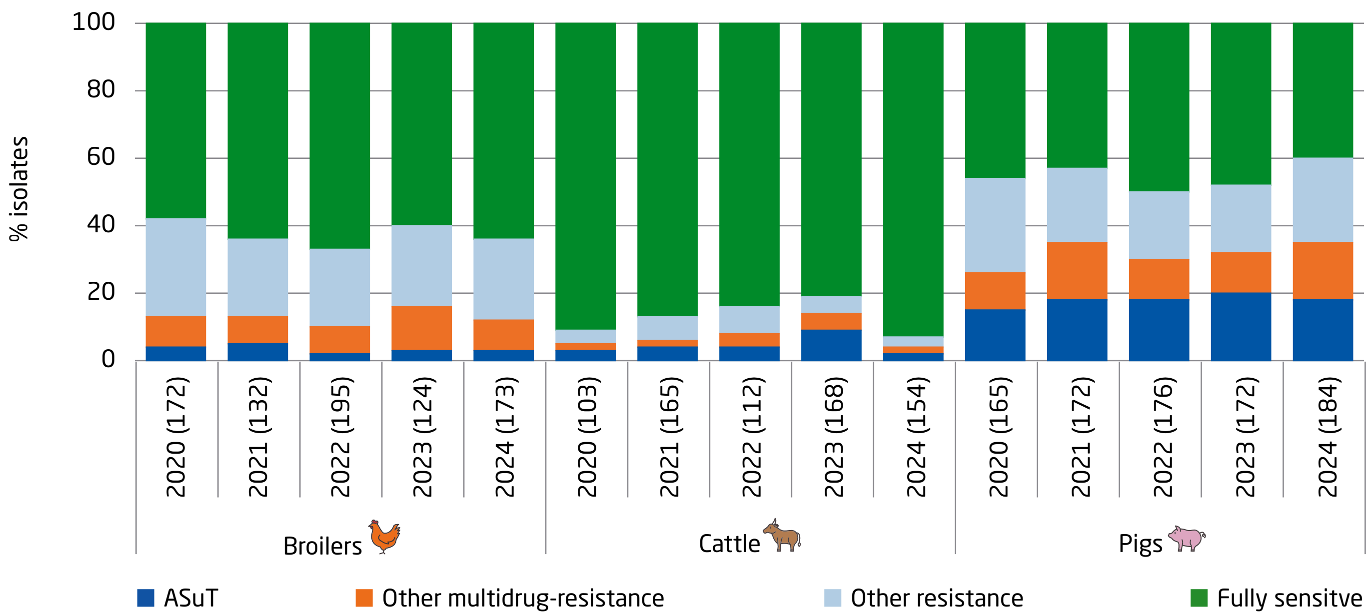
Resistance in indicator *E. coli*

Full susceptibility and multidrug-resistance in *E. coli* - stability in broilers and pigs, and a shift in calves

Over the last five years of monitoring, there have been no statistically significant trends in the occurrence of fully susceptible indicator *E. coli* (*E. coli* sensitive to all fifteen antibiotics tested) in Danish broilers, pigs and calves. However, in 2024 compared to 2023, the occurrence of fully susceptible *E. coli* increased in cattle (from 82% to 93%) and decreased in pigs (from 48% to 40%) (Figure 5.1).

The occurrence of multidrug-resistant indicator *E. coli* (*E. coli* resistant to three or more antibiotic classes) remained relatively constant in broilers and pigs, but it visibly decreased in calves (from 14% in 2023 to 4% in 2024), in a clear shift from the increasing trend observed in previous years (Figure 5.1).

Figure 5.1 Distribution (%) of fully susceptible, resistant and multidrug-resistant *Escherichia coli* isolates from broilers, cattle (calves) and pigs, Denmark, 2020-2024



The number of isolates included each year is shown in parentheses. An isolate is considered fully susceptible if sensitive to all antimicrobial agents tested, and multidrug-resistant if resistant to three or more antimicrobial classes included in the test panel. ASuT are the multidrug-resistant isolates resistant to ampicillin, sulfamethoxazole and tetracycline, which may also be resistant to other antimicrobials

Resistance towards 'Watch' and 'Reserve' antibiotics

Indicator *E. coli* from food-producing animals is monitored for resistance towards several antibiotics important for human treatment and classified as 'Watch' or 'Reserve' by the WHO (see textbox on Chapter 3 – AwaRe classification of antimicrobials in Denmark, 2024). As in previous years, resistance to colistin, meropenem, tigecycline or ceftazidime ('Reserve') was not detected.

Similarly, resistance to cefotaxime ('Watch') was not detected or detected at very low levels (up to 1%). Resistance to other 'Watch' antibiotics in 2024 were as follows: for ciprofloxacin, still very low levels (up to 1%) among isolates from cattle and pigs, and continued decrease in isolates from broilers (from 18% in 2022, to 15% in 2023, and 11% in 2024); for azithromycin, resistance was again detected in few isolates from pigs (3% in 2023 and 4% in 2024).

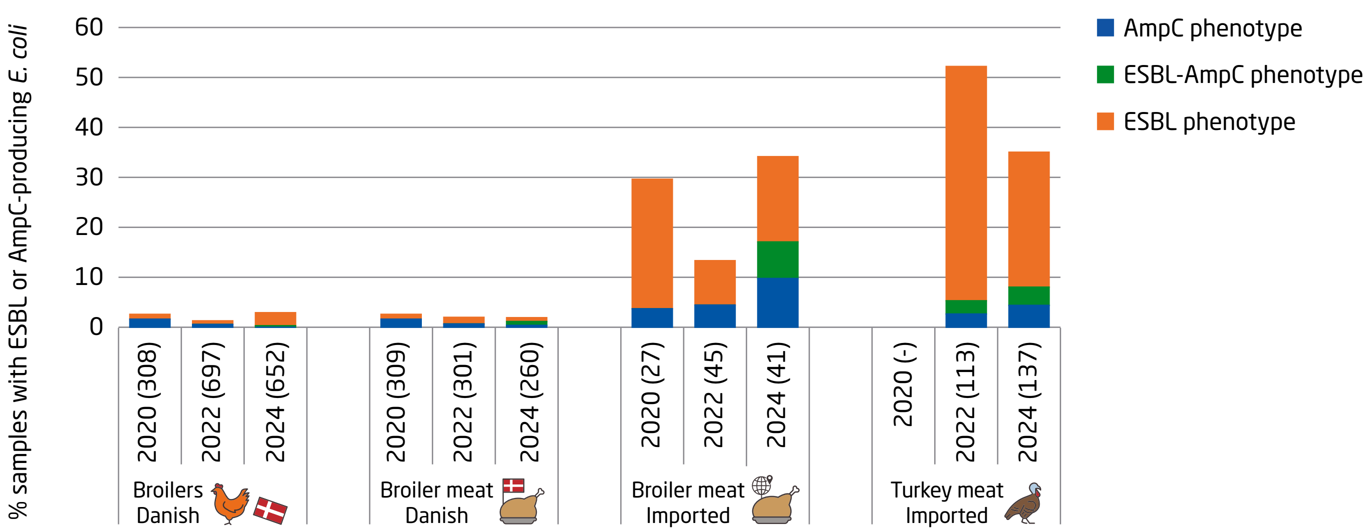
Occurrence of β-lactamase-producing *E. coli*

Occurrence of ESBL- /AmpC- producing *E. coli* – stable in domestic broilers and broiler meat, oscillating in imported poultry meat

In 2024, compared to the previous monitoring year, 2022, the occurrence of ESBL-/AmpC-producing *E. coli* remained low in samples from broilers and domestic broiler meat (3% and 2%, respectively), while it increased in samples from imported broiler meat (from 13% to 34%), and decreased in samples from imported turkey meat (from 52% to 35%) (Figure 5.2).

The testing of ESBL-/ AmpC-producing *E. coli* for resistance towards 'Reserve' antibiotics showed, like in previous years, no occurrence of resistance to imipenem, meropenem, or tigecycline, and resistance to colistin was only detected in isolates from imported turkey meat (4%). The resistance to 'Watch' antibiotics showed: an increase in occurrence of resistance to the second-generation cephalosporin cefoxitin in isolates from domestic and imported broiler meat and imported turkey meat; an increase in the occurrence of resistance to the fourth generation cephalosporin cefepime in isolates from broilers and domestic broiler meat (from 67% in 2022 to 100% in 2024; note however the low number of isolates in Figure 5.2 footnote); ertapenem resistance was not detected in broiler isolates (after 11% reported in 2022) and it was detected in isolates from imported turkey (4%); there was no detection of resistance to temocillin.

Figure 5.2 Occurrence (%) of samples with ESBL- and/or AmpC-producing *E. coli* from animals and meat recovered by selective enrichment, Denmark, 2020-2024



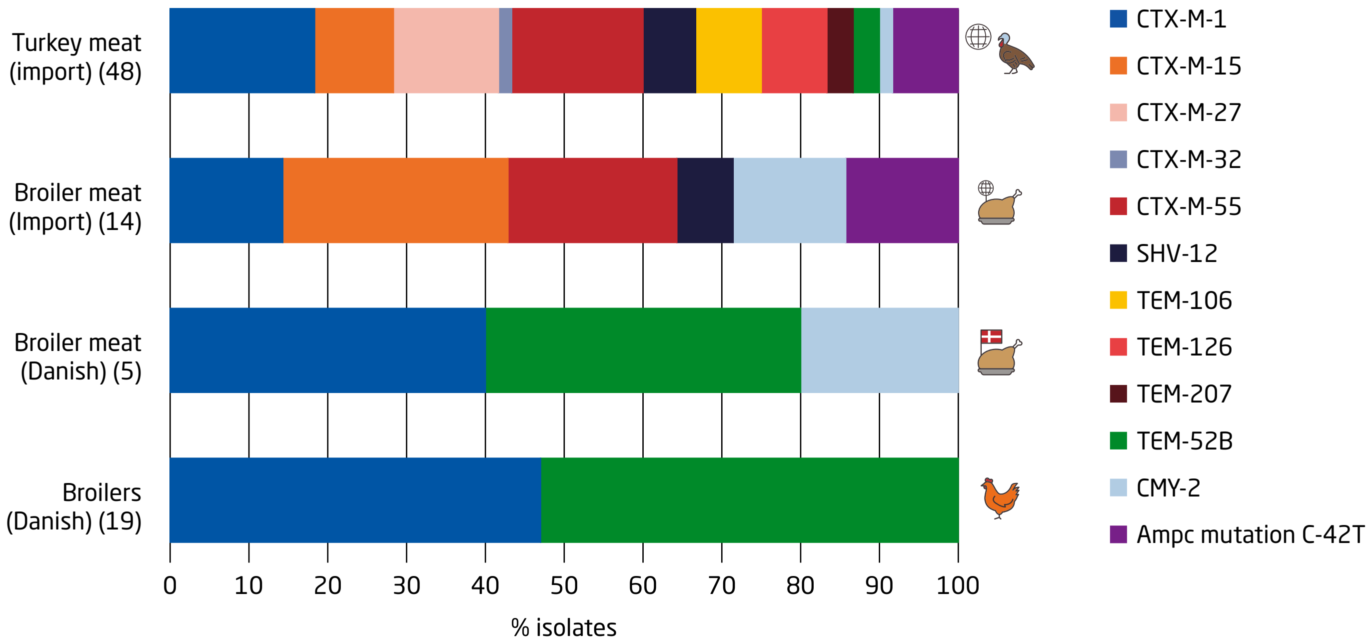
Classification of ESBL and/or AmpC phenotypes based on antimicrobial susceptibility testing. Number of samples tested per year is presented in parentheses. In 2024, the numbers of ESBL-/AmpC-producing *E. coli* isolates recovered were: 19 for broilers; 5 for domestic broiler meat; 14 for imported broiler meat; 48 for imported turkey meat

Genotypic background of ESBL- /AmpC- producing *E. coli* – Stable enzyme occurrence

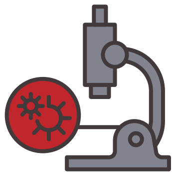
The genetic basis for ESBL and AmpC enzymes (see textbox *Extended-spectrum beta-lactamases (ESBL) and Cephalosporinases (AmpC)*) was detected in all ESBL-/AmpC-producing *E. coli* isolates (Figure 5.3). The detected enzymes corresponded to the phenotypes derived from the susceptibility testing for most isolates, except 12 isolates for which susceptibility testing revealed an ESBL- and AmpC-producing phenotype, while WGS only revealed the presence of genes encoding for ESBL enzymes.

Among the AmpC genotypes, as observed in previous years, resistance was conferred by upregulated AmpC promotor C-42T mutations, followed by the CMY-2 plasmid-mediated AmpC enzyme. Among the ESBL genotypes, ten different ESBL-encoding genes were detected. Overall, as observed previously, the most commonly observed ESBL-encoding gene was CTX-M-1, followed by CTX-M-15 and CTX-M-55. As already observed in 2022, among isolates from imported turkey meat, the encoding gene CTX-M-27 was considerably frequent, all detected ESBL enzymes were observed, and 15% of all isolates showed more than one ESBL-encoding gene.

Figure 5.3 Distribution of ESBL and AmpC enzymes detected by whole genome sequencing in β-lactamase-producing *E. coli* isolates from animals and meat recovered by selective enrichment, Denmark, 2024



Number of isolates recovered by selective enrichment methods for specific monitoring of ESBL/AmpC producing *E. coli* are indicated in parentheses. ESBL/AmpC enzymes were determined by whole genome sequencing of the recovered isolates



Extended-spectrum beta-lactamases (ESBL) and Cephalosporinases (AmpC)

Gram-negative bacteria, such as *E. coli*, resistant to β-lactam antibiotic(s) most commonly produce one or more β-lactamase enzymes, which hydrolyze the given antibiotic(s).

β-lactamases can be classified according to different structural and functional classification systems. The functional classification has the advantage to relate the enzymes to their ability to hydrolyze specific β-lactam classes, and to identify the possibility of their inactivation with β-lactamase inhibitor substances, thus supporting antimicrobial therapy choices in clinical practice.

According to their functional classification, β-lactamases can belong to three major groups, and several subgroups. In DANMAP, *E. coli* is monitored for ESBL and AmpC enzymes.

AmpC enzymes
AmpCs are active on cephalosporins and cephamycins, and usually resistant to inhibition by clavulanic acid. In large amounts, especially against low amounts of β-lactams, AmpCs can also provide resistance to carbapenems. These enzymes are encoded on the chromosomes of many *Enterobacteriaceae*, however, plasmid-mediated AmpCs also occur for example in the families CMY or DHA, although less commonly than plasmid-mediated ESBLs. Some AmpC variants have greater activity against ceftazidime (a third generation cephalosporin), and are therefore called extended-spectrum AmpCs.

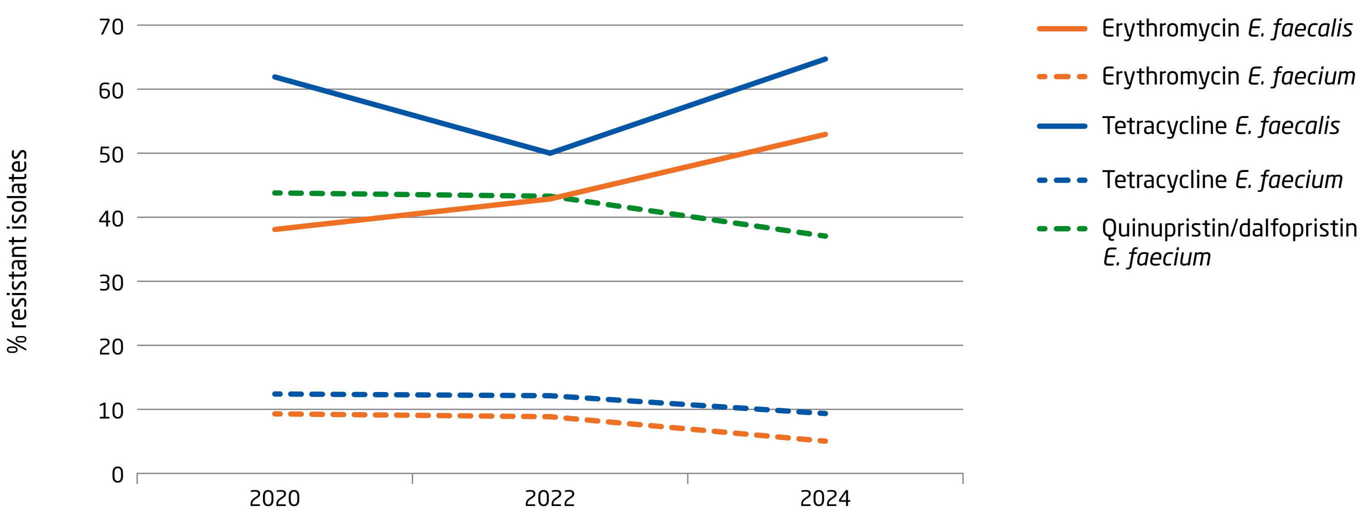
ESBL enzymes
The largest functional group of β-lactamases includes 12 subgroups. Subgroup 2be comprises the ESBLs. ESBLs hydrolyze penicillins and early-generation cephalosporins, and additionally hydrolyze one or more third generation cephalosporins. They include mostly enzymes of the families TEM, SHV, and the more rapidly proliferating CTX-M.

Resistance in *Enterococcus faecalis* and *Enterococcus faecium* from broilers

In 2024, 17 *E. faecalis* and 278 *E. faecium* isolates were obtained from broilers at slaughter and tested for antimicrobial susceptibility. Overall, 29% of the *E. faecalis* and 85% of the *E. faecium* isolates were fully susceptible, which represents a decrease for *E. faecalis* (from 39%) and an increase for *E. faecium* (from 52%), compared to 2022.

None of the enterococci isolates showed resistance to chloramphenicol or gentamicin ('Access' antibiotics); teicoplanin or vancomycin ('Watch' antibiotics); daptomycin, linezolid or tigecycline ('Reserve' antibiotics). Only 1% and 3% of the *E. faecium* showed resistance to ampicillin ('Access') and ciprofloxacin ('Watch'), respectively. Resistance to tetracycline ('Access') and erythromycin ('Watch') was common among both species, although at comparatively higher levels in *E. faecalis* than *E. faecium*. Quinupristin/dalfopristin ('Reserve') resistance was common among *E. faecium* isolates. Compared to 2022, resistance towards these antibiotics has increased in *E. faecalis* and decreased in *E. faecium* (Figure 5.4).

Figure 5.4 Resistance (%) among Enterococci isolates from broilers, Denmark, 2020-2024



Trends of antimicrobial consumption and antimicrobial resistance in indicator *E. coli*

Contrasting trends for calves

In 2024, the previously observed increase in the use of amphenicols and macrolides in calves continued (see Chapter 2, Figure 2.6). Unlike what was observed in 2023, the occurrence of resistance in indicator *E. coli* from calves did not follow a similar trend. Despite the overall increase in antimicrobial use in calves, the occurrence of resistance in *E. coli* showed a general decrease for most tested substances. Figure 5.5 shows the continued increase in florfenicol consumption contrasting with a sharp decrease in chloramphenicol-resistant *E. coli*.

Resistance trends in *E. coli* indicative of trends in antimicrobial use in weaners and finishers

After a consecutive increase in the use of aminoglycosides in weaners, primarily neomycin and apramycin, in 2022 and 2023 (see Chapter 2, Figure 2.5a), the use of both antibiotics in this age group declined slightly in 2024. Resistance of indicator *E. coli* from pigs to the aminoglycosides in the test panel (amikacin and gentamicin) is usually absent or very low. However, in 2024, a modest increase was observed, from below 1% to 2% for amikacin and from 2% to 4% for gentamicin (Figure 5.6).

Similarly, the use of macrolides in finishers showed a continued increase in 2024, following what was previously observed in 2022 and 2023. Indicator *E. coli* is routinely tested for resistance towards the macrolide azithromycin, usually showing very low levels of occurrence. In 2024, a modest increase in azithromycin resistance was observed, coinciding with the ongoing increased use of macrolides in finisher pigs (Figure 5.7).

Figure 5.5 Use of florfenicol (DAPD) in calves and resistance to chloramphenicol (%) among indicator *E. coli* from calves at slaughter, Denmark, 2020-2024

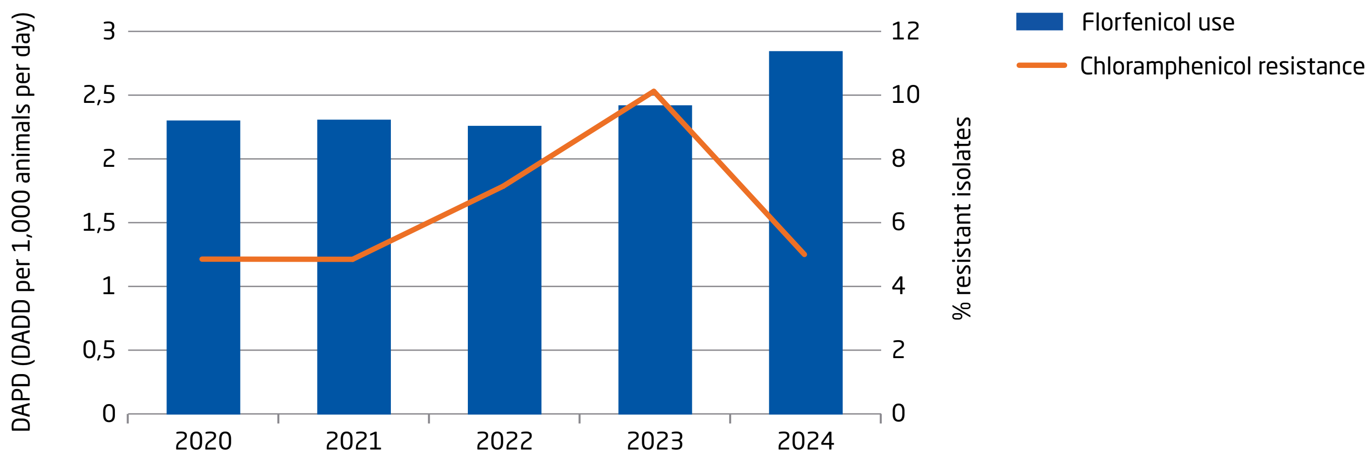


Figure 5.6 Use of aminoglycosides (DAPD) in weaners and resistance to aminoglycosides (%) among indicator *E. coli* from pigs at slaughter, Denmark, 2020-2024

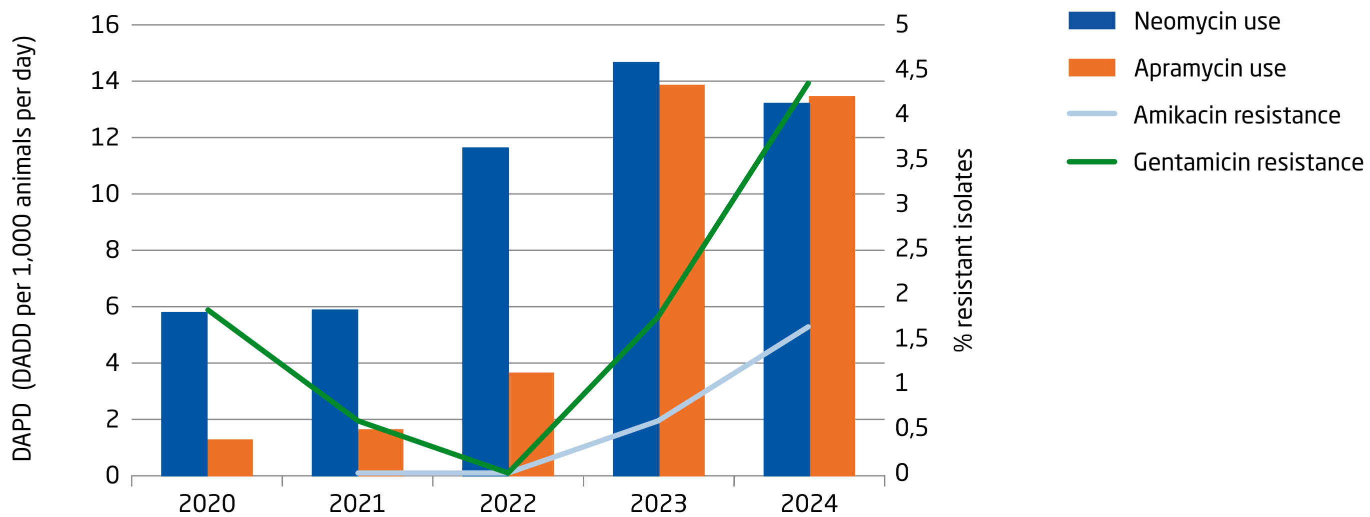
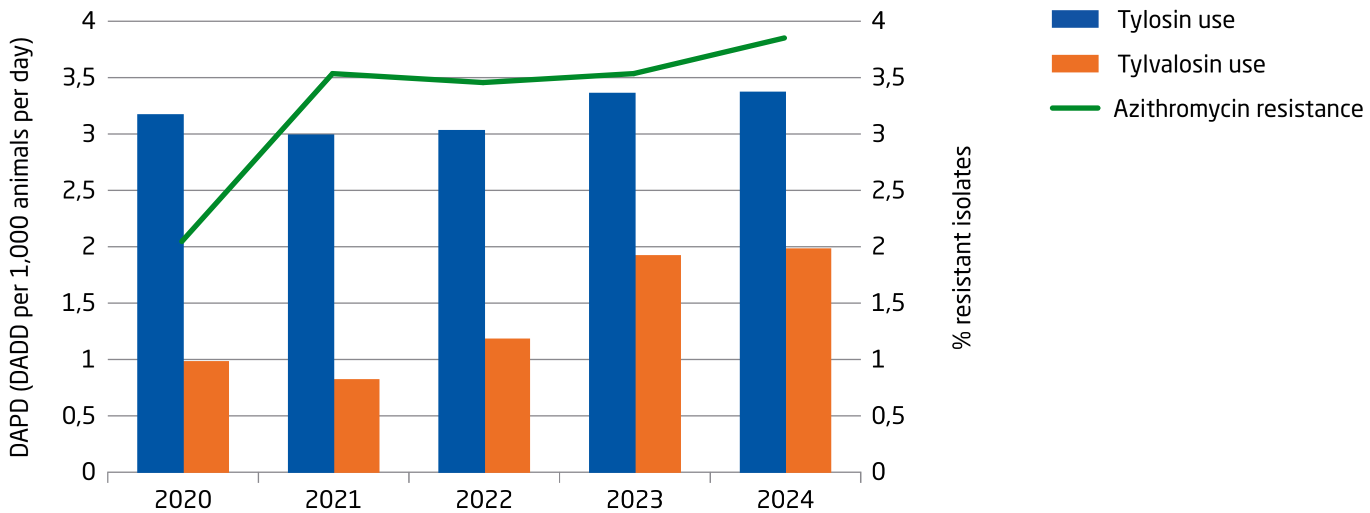


Figure 5.7 Use of macrolides (DAPD) in finishers and resistance to macrolides (%) among indicator *E. coli* from pigs at slaughter, Denmark, 2020-2024



6. Resistance in human pathogens

DANMAP's surveillance of antimicrobial resistance in bacteria from human infections is based on information on clinical isolates and covers all antimicrobial susceptibility testing performed in Denmark. Data include phenotypic results from all Departments of Clinical Microbiology (DCM) and phenotypic and/or genotypic results from isolates submitted to national reference laboratories (NRLs) at Statens Serum Institut (SSI). Data for DANMAP is either extracted from the Danish Microbiological database (MiBa) or collected from the registers at the NRL.

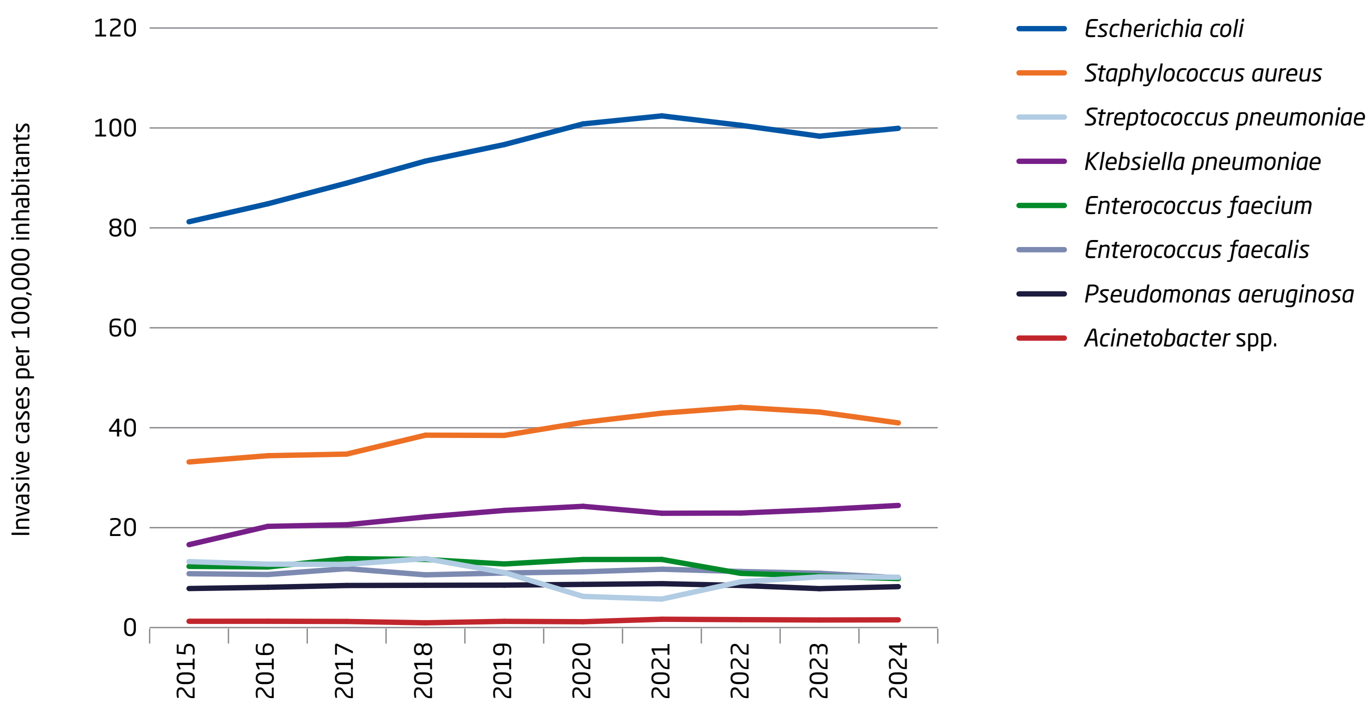
The number of invasive bacterial species monitored is still stable in 2024

DANMAP collects data on the eight most common bacterial species causing invasive infections in humans. The total number of unique cases with these species has been continuously increasing since 2014 (+22%), but appears stable since 2021 with 12,122 cases in 2024 (12,115 cases in 2023).

Escherichia coli is – and has been - the most frequent cause of invasive infections, accounting for an approximate share of 50%. In 2024 there were 5,957 cases of *E. coli*, with a 30% increase in the number of invasive isolates over the last decade. *Staphylococcus aureus* bacteraemia accounted for 2,442 patient cases (1,876 in 2015, 30% increase), followed by *Klebsiella pneumonia* with 1,457 patient cases (939 in 2015, 55% increase).

The increasing numbers of invasive infections mirror an increase in hospitalised patients and at-risk groups (elderly and immunocompromised/chronically ill patients) and may in addition be associated with a higher use of invasive medical procedures and surgeries. In addition, the number of microbiological samples received for analysis at the DCM has increased considerably during the past decade. In 2024, a total of 3,153 patients per 100,000 inhabitants had at least one blood culture taken compared to 2,611 patients per 100,000 inhabitants in 2015, an increase of 21%. Simultaneously, the total number of positive blood cultures from bacterial species under surveillance in DANMAP increased markedly, by 29%.

Figure 6.1 Incidence of monitored invasive cases per 100,000 inhabitants by species, Denmark, 2015-2024



Resistance in monitored bacterial species in Denmark

Resistance in *E. coli* has remained below the 10% percentile for most antimicrobials for the past decade. Since 2015 decreasing trends in resistance in invasive isolates were noted particularly for ciprofloxacin (-1.1 percentage points (pp)), 3rd generation cephalosporins (-0.7 pp) and gentamicin (-2.5 pp) and increasing trends for piperacillin-tazobactam (+1.5 pp), Figure 6.2. This trend is mirrored in isolates from urinary tract infections. The COVID-19 pandemic enforced many of these trends. However, since 2021, increases in resistance towards most of the monitored antibiotics were observed. For *K. pneumoniae* similar trends were observed, the decreases in resistance to cephalosporins, fluoroquinolones and gentamicin being even more notable. Table 6.1 shows resistance levels in both species for the past five years span, 2019 and 2024.

Figure 6.2 Resistance in invasive isolates of *E. coli* and *K. pneumoniae*, 2015-2024

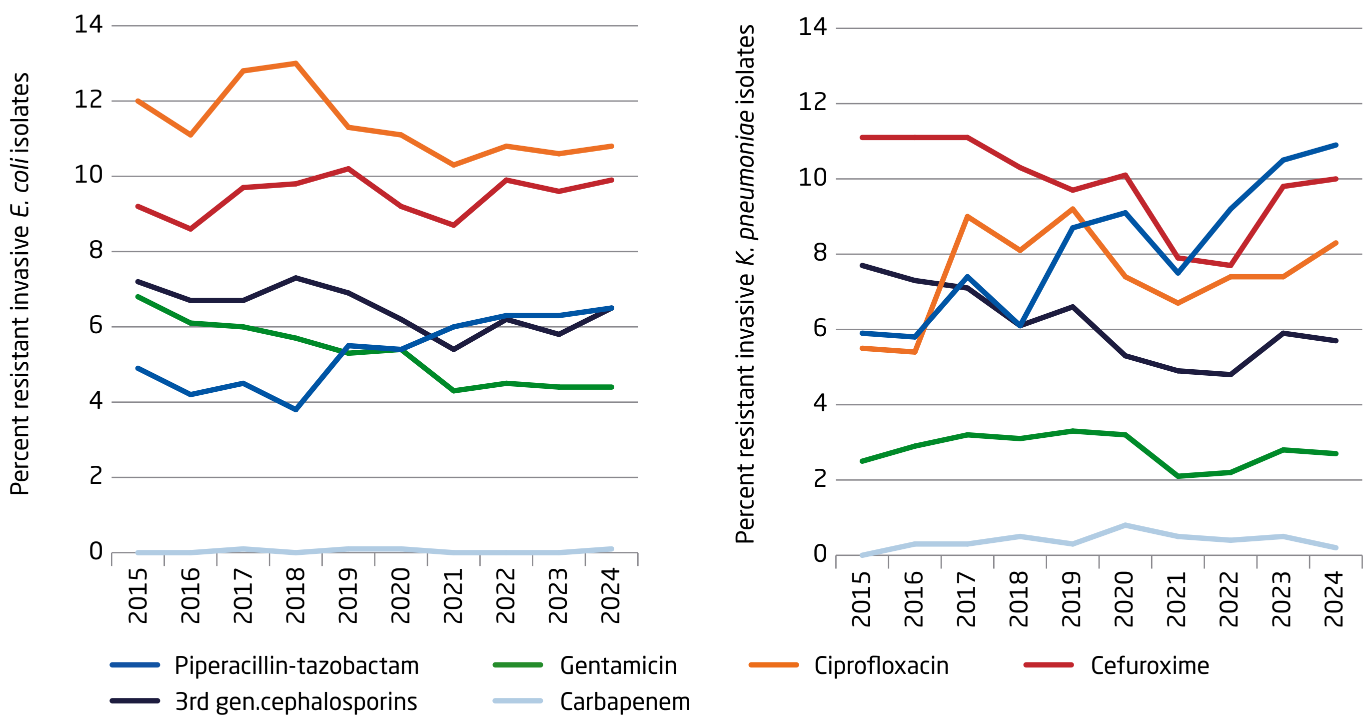


Table 6.1 Resistance (%) in *E. coli* and *K. pneumoniae* from urine and blood cultures, 2019 and 2024

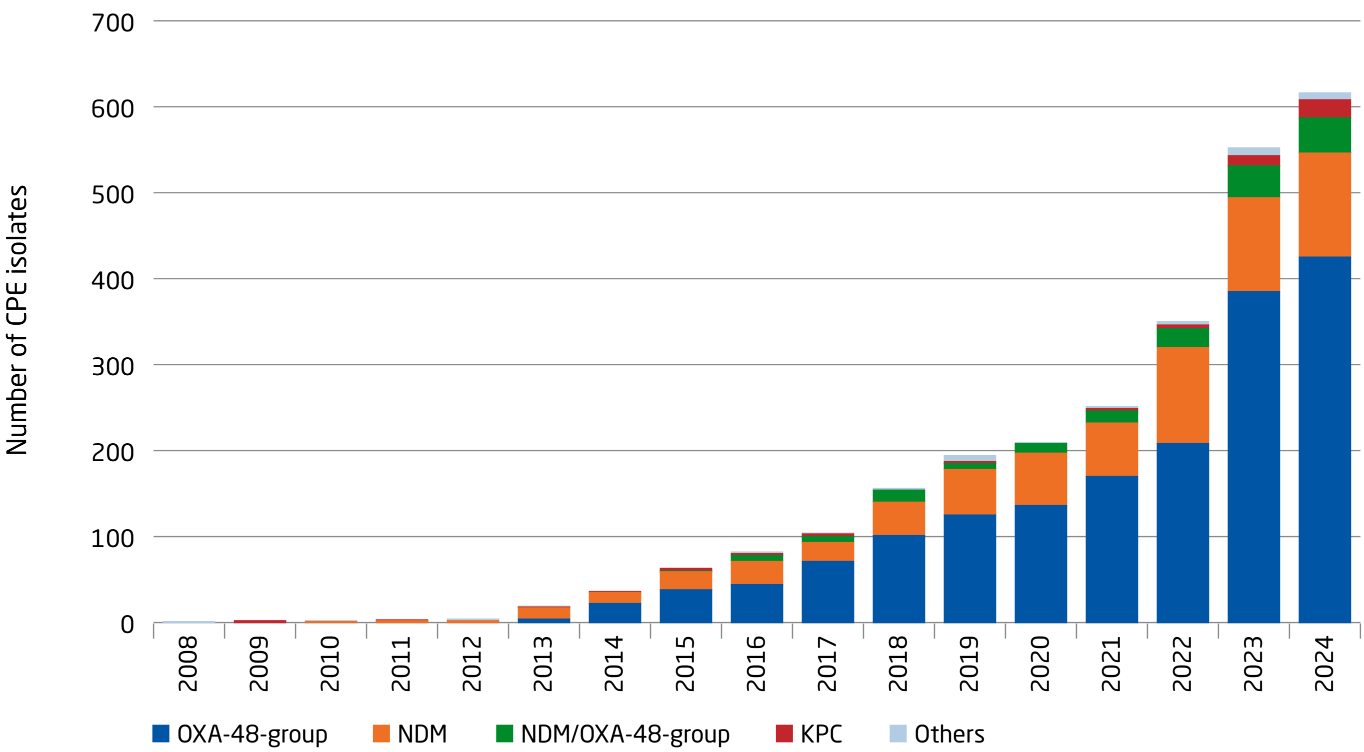
	E. coli				*K. pneumoniae*			
	2019 (%)		2024 (%)		2019 (%)		2024 (%)	
	Invasive	Urines from PHC*	Invasive	Urines from PHC	Invasive	Urines from PHC	Invasive	Urines from PHC
Ampicillin	45.7	38.1	42.3	34.3	NA	NA	NA	NA
Mecillinam	-	5.3	-	3.9	-	11.5	-	7.9
Amoxi-clav	-	-	-	-	-	-	-	-
Sulfonamides	-	27.9	-	23.7	-	18.9	-	14.2
Ciprofloxacin	11.3	8.0	10.8	7.7	9.2	5.5	8.3	5.4
Pip-tazo	5.5	-	6.5	-	8.7	-	10.9	-
Cefur	10.2	-	9.9	-	9.7	-	10.0	-
3rd gen ceph	6.9	5.2	6.5	5.6	6.6	4.5	5.7	4.5
Gentamicin	5.3	-	4.4	-	3.3	-	2.7	-
Carbapenem	0.1	-	0.1	-	0.3	-	0.2	-

* PHC = Primary health care, NA = Not applicable

Increasing numbers of CPO isolates associated with domestic outbreaks

Carbapenemase-producing organisms (CPO) have been notifiable since 2018, which includes reporting both laboratory and relevant epidemiological findings. All isolates received at SSI are analysed by whole genome sequencing (WGS). In 2024, a total of 616 CPE isolates were reported from 497 patients compared with 552 CPE from 458 patients in 2023, resulting in a 12% increase of CPE isolates and a 9% increase in numbers of patients compared to 2023. The numbers of CPO and distribution of the most common carbapenemase genes are presented in Figure 6.3.

Figure 6.3 Numbers of CPO isolates and most common carbapenemase genes received at SSI, 2008 to 2024



More than one isolate from the same patient was included if the isolates belonged to different bacterial species and/or if the isolates harboured different carbapenemases

Carbapenemase-producing organisms (CPO) and Enterobacterales (CPE)

Carbapenemase-producing organisms (CPO) are of national and international concern as they are resistant to beta-lactam antimicrobials including carbapenems, which are used to treat serious infections, for example caused by multi-resistant bacteria. CPO infections are associated with high mortality and healthcare costs due to longer treatment and lengths of hospital stay. Importantly, CPO have the potential for transmission of resistance to other bacteria via mobile genetic elements and cause increasingly outbreaks in healthcare settings.

Detection of CPO was made notifiable in Denmark in September 2018.

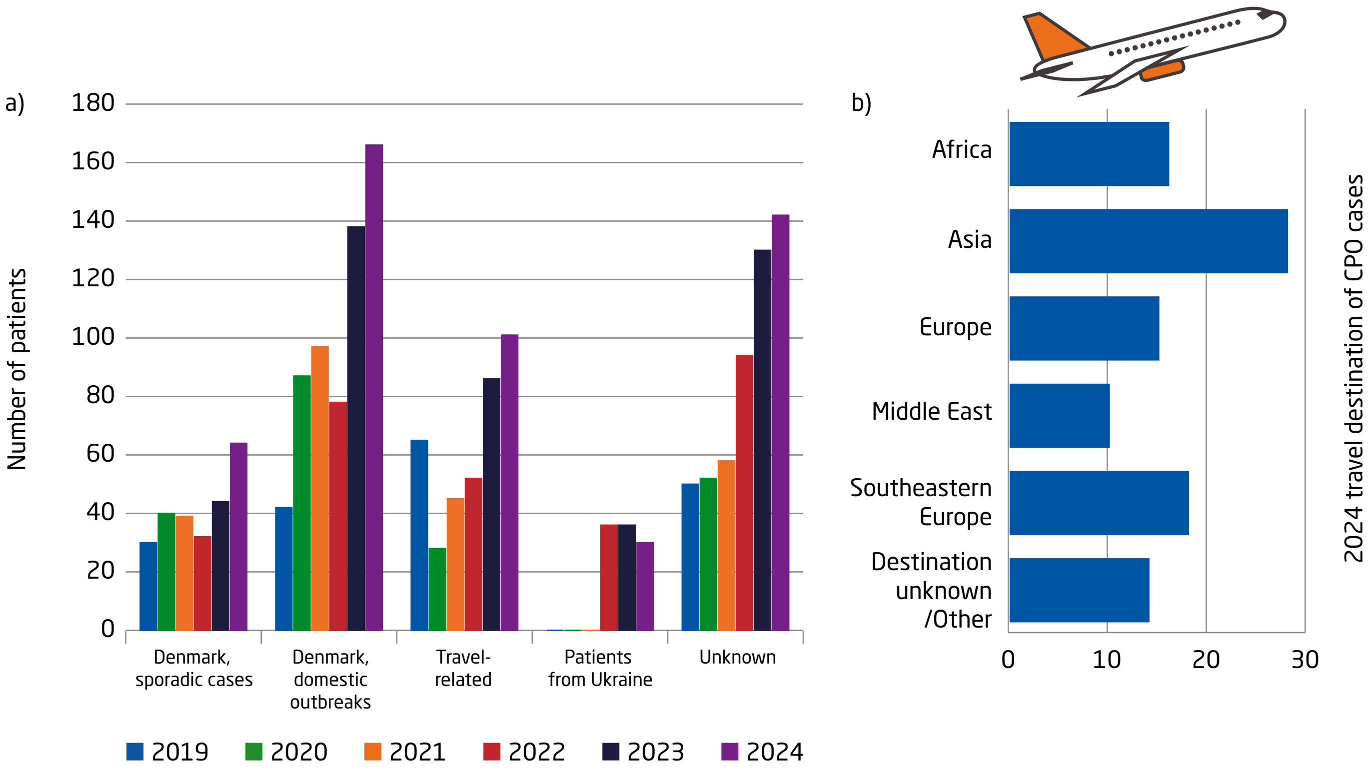
CPO comprise of two main groups:

- Intestinal bacteria (Carbapenemase-producing Enterobacterales [CPE]) e.g. *Escherichia coli, Klebsiella pneumoniae*
- Environmental bacteria e.g. *Pseudomonas aeruginosa, Acinetobacter baumannii*

Many of the new CPO cases were associated with CPO outbreaks, the majority at hospitals: 33 registered outbreaks in 2024 (166 new patients) compared to 26 outbreaks in 2023 (138 new patients). Acting in accordance with the CPO guidelines is of utmost importance in order to prevent the further spread of CPO.

In 2024, for 101 persons the acquisition of CPO was associated with former travel, (86 persons in 2023 and 52 in 2022). The destination of travel can be seen in Figure 6.4. Due to the still ongoing conflict in Ukraine, Denmark receives patients as part of medical evacuations, (41 patients in 2024) of which 30 patients carried altogether 57 CPOs. As in former years, for some patients no information regarding travel or probable place of origin could be obtained; 142 patients in 2024.

Figure 6.4 a) Classification of CPO cases in 2019-2024 b) World regions where patients in 2024 with travel-related cases have travelled



The number of vancomycin-resistant enterococci (VRE) continues to decrease

In 2024, 613 VRE isolates were detected in Denmark - a 15% decrease compared to the 722 isolates found in 2023. This continues the marked decrease from 2022 after increases observed for most years during the past decade and particularly from 2020 to 2022. Although most VRE are detected in urinary samples, many of these may not be associated with a clinical infection but rather interpreted as an expression for colonization in patients at risk. The decreasing numbers point towards less attention being paid to detection of VRE isolates at hospitals. This should not lead to neglect of the importance of infection prevention and control teams to control outbreaks in healthcare facilities and implement prevention strategies.

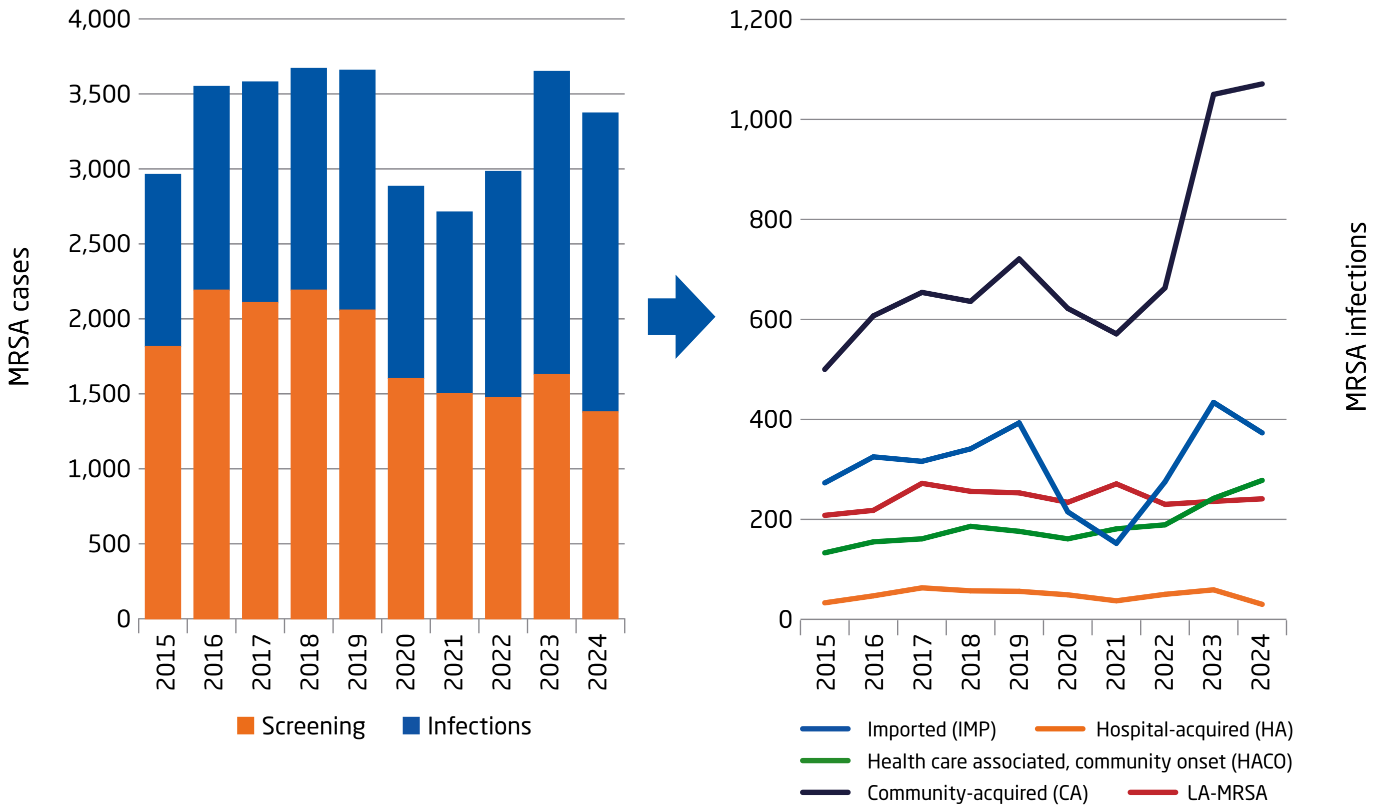
Staphylococcus aureus - new MRSA cases stabilize after the pandemic

In 2024, the number of invasive *S. aureus* isolates from blood was slightly lower with 2,461 cases compared to 2,571 cases in 2023. Resistance levels did not change notably and remained for most cases well below the 10% percentile; noteworthy are decreasing trends for resistance to penicillin, 69% in 2023, (77% in 2014 and around 86% in the mid-90ies). Forty-seven of the bacteraemia cases were caused by MRSA out of which seven were livestock-associated MRSA (LA-MRSA).

Surveillance of all MRSA cases, e.g. infected and colonized persons, showed a decrease of 8% in 2024 (3,372 cases) compared to 2023 (3,649 cases) and a 14% increase compared to 2015 (2,962 cases), Figure 6.5. LA-MRSA constituted 22% of all new MRSA cases and primarily affected persons working with pigs and their households. Trends in MRSA in infected persons based om their epidemiological classification is presented in Figure 6.5.

The number of MRSA outbreaks in hospitals, nursing homes and other institutions remained at the same level with 38 outbreaks involving 191 patients in 2024 compared to 41 outbreaks with 199 patients in 2023.

Figure 6.5 Number of MRSA under surveillance (screening and infections), and epidemiological classification of infection cases, Denmark, 2015-2024



Neisseria gonorrhoeae – resistance to antimicrobials used for treatment of gonorrhoeae is currently not of concern in Denmark

Gonorrhoea, the second most common sexually transmitted bacterial infection in Denmark, is caused by *N. gonorrhoeae* (gonococci) and the DCMs have submitted isolates to SSI since 1962. Over the past decade the number of received isolates and of reported cases increased significantly. In 2024, the reference laboratory at SSI received 1,852 isolates from 1,803 individual cases. Ciprofloxacin resistance was at 61%. Azithromycin-resistance was found in 3.5% of tested isolates in 2024 compared to 6.0% of tested isolates in 2023.

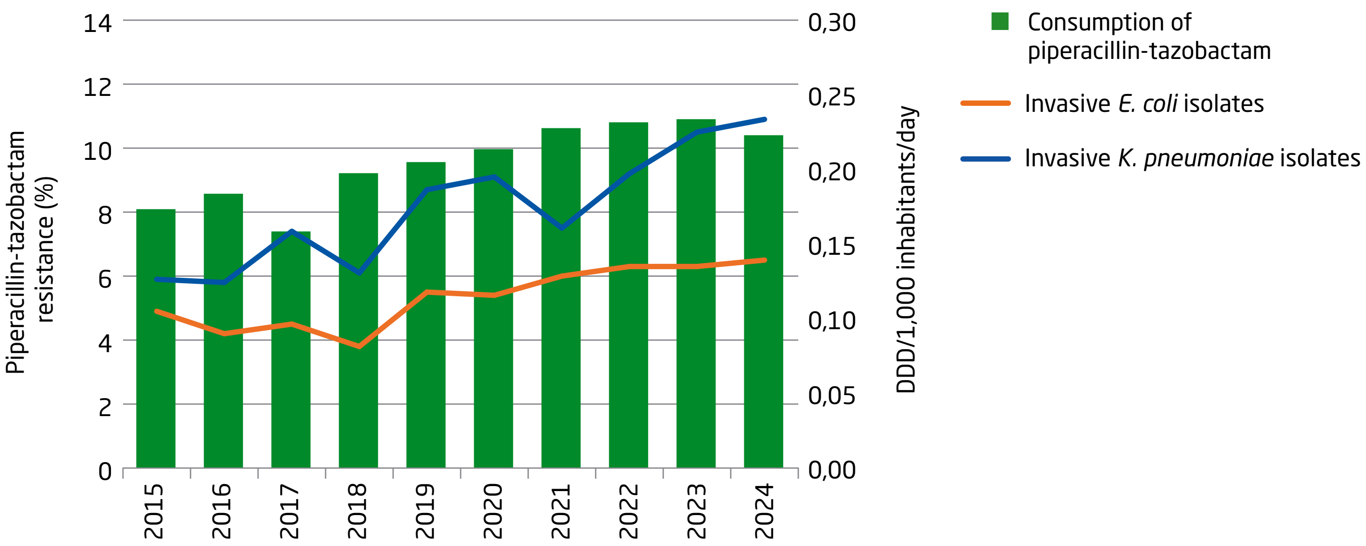
Although the occurrence of resistance among gonococci is currently not of concern in Denmark, the frequent emergence of resistance mechanisms in *N. gonorrhoeae* globally compromises the management, prevention and control of the infection in many countries and highlights that surveillance of resistance trends is vital to ensure that treatment for gonorrhoea remains effective.

Trends of antimicrobial consumption and resistance in humans

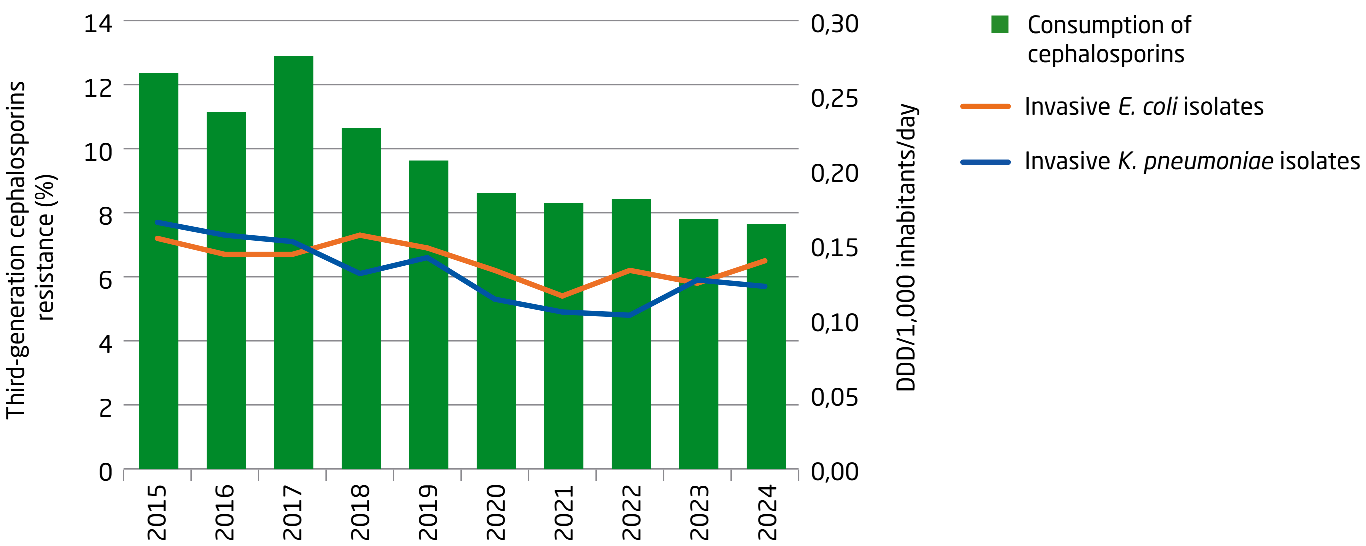
Over the last decade, there has been several changes in consumption of antimicrobials for humans, followed by changes in resistance trends. A steep increase was observed for combinations of penicillins and beta-lactamase inhibitors in hospital care. This was followed by an increase in the occurrence of resistance towards piperacillin-tazobactam in invasive *E. coli* and *K. pneumoniae* from human cases, (Figure 6.6a). On the other hand, reduced consumption of cephalosporins was followed by reduced trends in resistance towards this antibiotic in invasive *E. coli* and *K. pneumoniae*, (Figure 6.6b).

Figure 6.6 Resistance (%) in invasive *Escherichia coli* and *Klebsiella pneumoniae* combined with antimicrobial consumption (DID), Denmark, 2015-2024

a) Piperacillin-tazobactam



b) Cephalosporins



7. Resistance in animal pathogens

Surveillance of antimicrobial resistance in 2024 focused on pathogenic bacteria from acute mastitis in dairy cows and from pigs and included results obtained through antimicrobial susceptibility testing (AST).

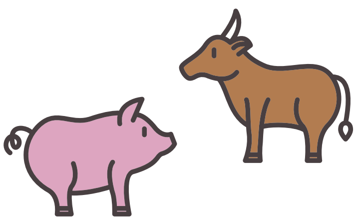
Resistance in pathogenic bacteria from acute mastitis in dairy cows

In dairy cows, 487 milk samples from acute mastitis cases were analysed, yielding 462 isolates, of which 85.9% were well-known mastitis pathogens. The most frequently identified species were *Streptococcus uberis* (27.5%), *Escherichia coli* (20.1%), *Staphylococcus aureus* (13.4%), and *Streptococcus dysgalactiae* (10.8%), coagulase-negative staphylococci (CoNS) (5.4%), *Trueperella pyogenes* (3.2%), *Streptococcus agalactiae* (2.8%) and *Klebsiella pneumoniae* (2.6%). In addition, we identified a number of bacterial species and yeasts found in less than 2% of the milk samples. Most pathogenic bacteria displayed low frequencies of phenotypic resistance. Notably, 19.7% of *S. uberis* isolates and 9.1% of *S. agalactiae* isolates displayed borderline resistance to penicillin. Since penicillin is the most widely used drug for treatment of dairy cattle in Denmark, these findings are significant. However, most resistant isolates had a MIC of 0.25 mg/L, just above the tentative ECOFF of 0.12 mg/L, making the clinical relevance uncertain in the absence of established breakpoints. Resistance to tetracycline was observed in *S. uberis* (19.7%), *S. dysgalactiae* (14.0%) and *S. agalactiae* (81.8%). Among *E. coli* isolates, 10–13.5% were resistant to ampicillin, tetracycline, sulfamethoxazole and trimethoprim. One *E. coli* isolate (ST46) displayed an extended-spectrum β-lactamase (ESBL) phenotype and was confirmed by sequencing to carry *bla*CTX-M-15. Among *K. pneumoniae* isolates, 91.7% were resistant to ampicillin, reflecting intrinsic resistance, while smaller proportions were resistant to tetracycline (16.7%) and trimethoprim (8.3%). Other mastitis pathogens generally exhibited very low levels of resistance (0–4.7%).

Resistance in pathogenic bacteria from pigs

In pigs, AST covered isolates of *Actinobacillus pleuropneumoniae*, *Bordetella bronchiseptica*, haemolytic and non-haemolytic *E. coli*, *Klebsiella pneumoniae*, *Salmonella enterica*, *Staphylococcus hyicus* and *Streptococcus suis*. Overall resistance frequencies were similar to 2023 (1-year comparison) and 2019 (5-year comparison), but important shifts were noted. Haemolytic *E. coli* showed significantly increased resistance to amoxicillin-clavulanic acid (22.4%), florfenicol (23.6%), gentamicin (46.5%), neomycin (60.0%) and spectinomycin (66.9%). The rapid increase in neomycin resistance is of particular concern because neomycin is one of few drugs recommended as first-line treatment for post-weaning diarrhoea. The increasing resistance to gentamicin is also concerning, given its classification as critically important for human medicine. The rise is thought to be linked to selection pressure from apramycin use, as most gentamicin resistance genes also confer resistance to apramycin. Resistance to 3rd generation cephalosporins (cefpodoxime) increased from 4.7% in 2023 to 8.2% in 2024, although this change was nonsignificant.

Among other pig pathogens, non-haemolytic *E. coli* showed significantly increased resistance to amoxicillin-clavulanic acid. In contrast, *Salmonella enterica* displayed significantly decreased resistance to florfenicol and gentamicin, and *S. hyicus* displayed decreased resistance to tiamulin, although the latter finding was based on few isolates and should be interpreted with caution.



8. One Health AMR

The zoonotic transmission of extended spectrum beta-lactamase-producing *E. coli* (here abbreviated to ESBL Ec), has been indicated as a possibility in many countries, including Denmark (see DANMAP 2024, Chapter 3, Textbox 3.1), underlining the importance of monitoring the occurrence of these bacteria in animals and humans in an integrated approach.

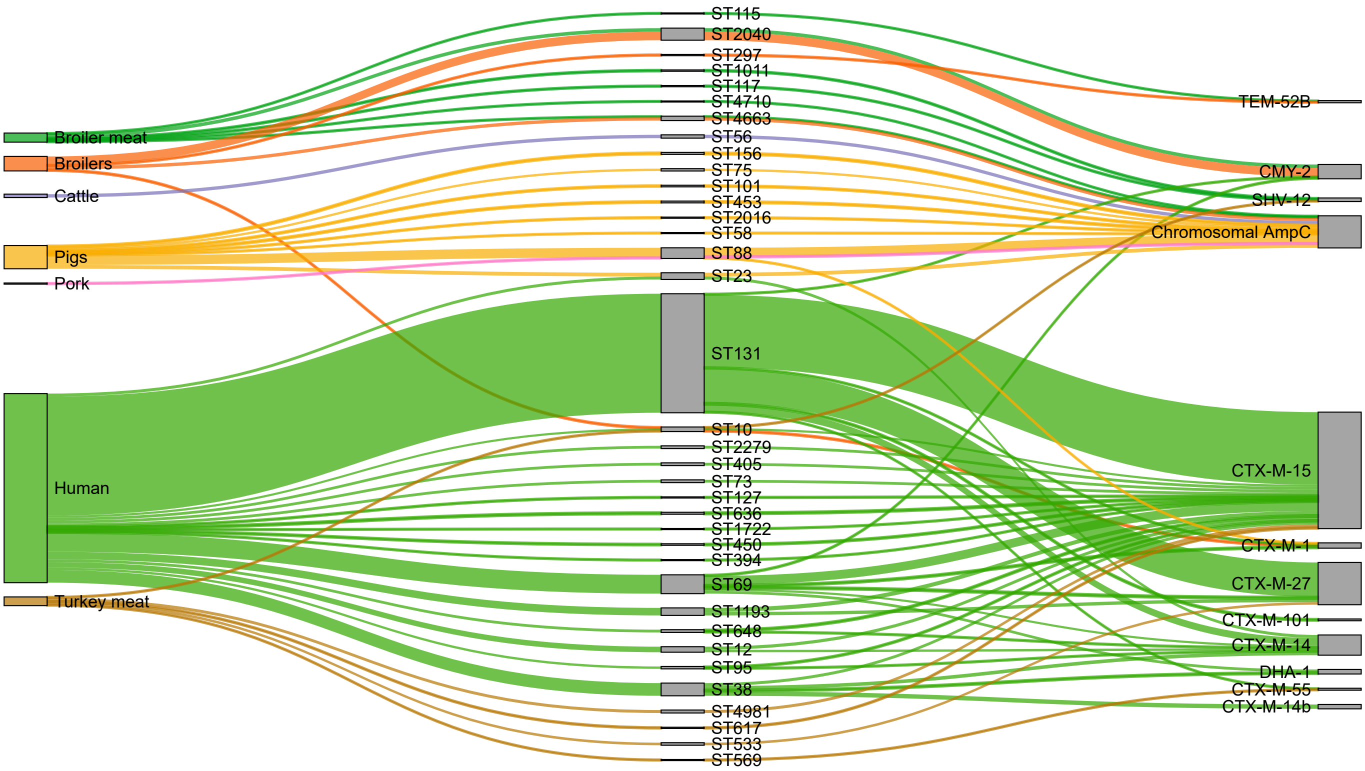
Here we map the frequency of multi-locus sequence types (MLST) and resistance genes and mutations in ESBL Ec recovered from livestock animals and meat and from humans. The analysis involved ESBL/AmpC- producing *E. coli* isolates from human blood stream infections, food-producing animals and meat. A total of 2,068 isolates from 2018 through 2024 were included with 1,300 from humans, 384 from meat and 384 from animals.

Source of ESBL Ec and their MLSTs and ESBL/AmpC genotypes

Sequence types (ST) and ESBL/AmpC genes and mutations were compared using a Sankey diagram (Figure 8.1). As in the previous years, limited overlap was found in the combination of STs and resistance genotype in isolates from humans vs. animals and meat.

Only the AmpC plasmid-mediated gene *CMY-2*, and the ESBL genes *CTX-M-1*, *CTX-M-15*, *CTX-M-27*, *CTX-M-55* and *SHV-12* were found in both humans and food-producing animals or meat. Interestingly, the ESBL genes found in turkey meat were primarily of the *CTX-M-15* and *CTX-M27*-kind, the two most common ESBL genes among human isolates. The *CMY-2* AmpC gene was almost exclusively found among isolates from broilers and broiler meat, and in few isolates from humans and turkey meat. The *CTX-M-1* gene was mostly found among human isolates, but also in pig and broiler isolates. All isolates from cattle harboured a C-42T mutation, which was not detected among the selected human isolates.

Figure 8.1 Sankey diagram showing the host, MLST and ESBL/AmpC gene or mutation of the included isolates, Denmark, 2018-2024



9. Timeline

Early 1980's

Clinical microbiology and principles of rational antibiotic use introduced as part of medical training at universities

1986

Antimicrobial prescription guidelines for doctors in "The little green" published by Danish Medical Association

1993

Cascade rules for veterinary medicines

1994

MedStat Database with human use of medicinal products

1995

DANMAP Surveillance in food animals, food and humans

1995-1996

- VASC* contracts with farmers
- Veterinarians non profit on sale

1995-1999

Industry stop for antimicrobial growth promotors

1996

Guidelines for antimicrobial use in pigs and cattle

1997

1998

1999

2000

VetStat data collection

Regulation on stop for antimicrobial growth promotors

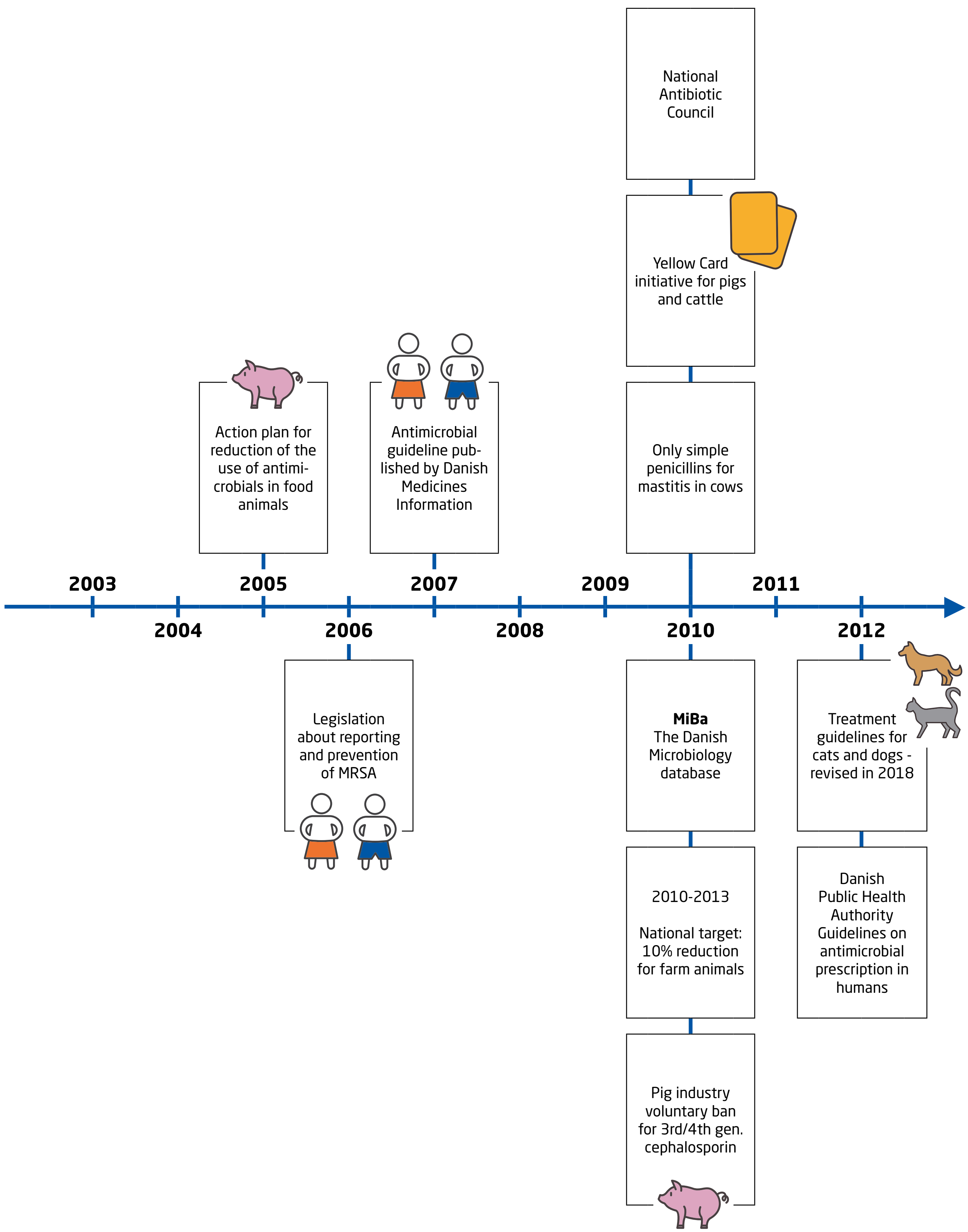
2001

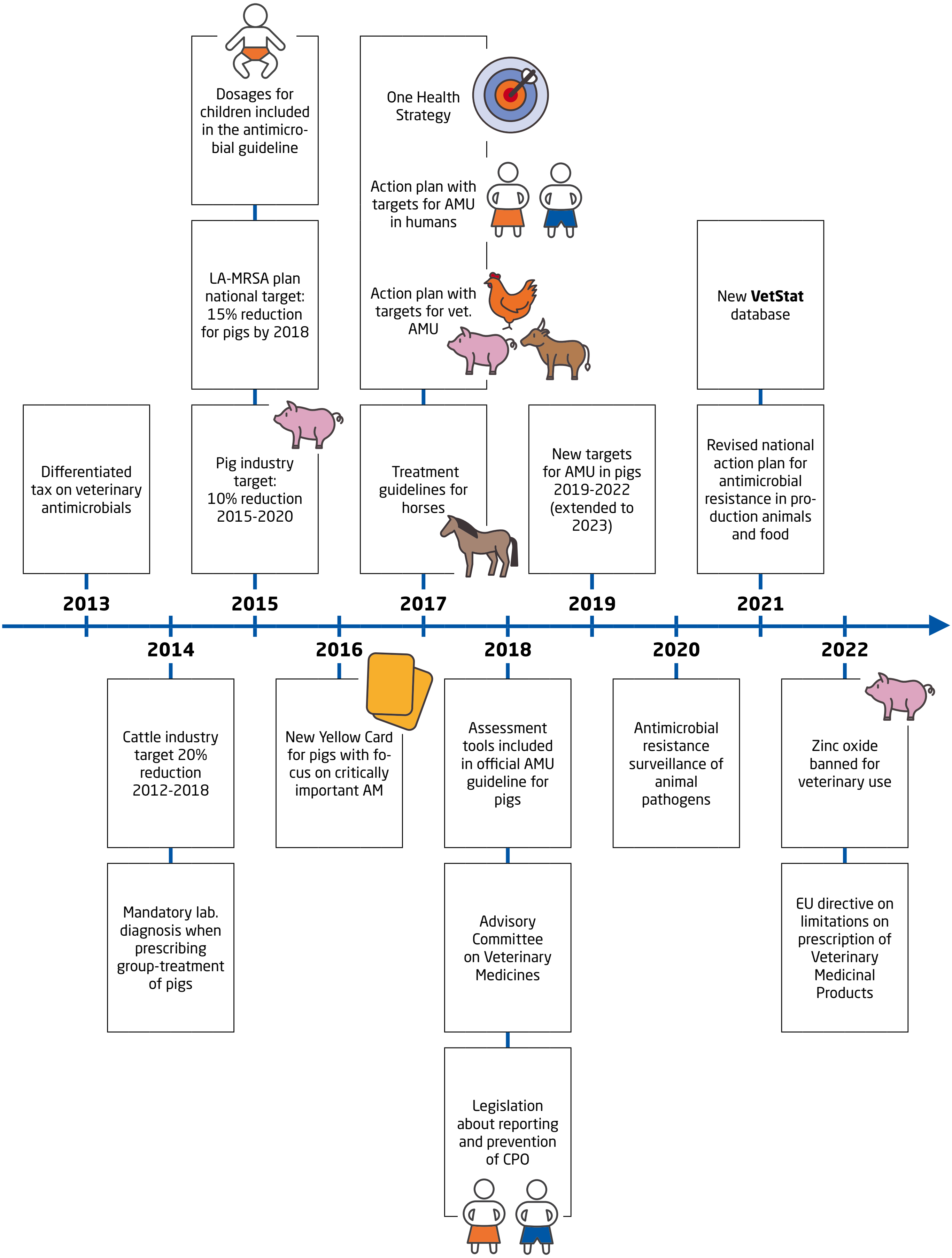
2002

Restrictions on fluoroquinolones for food animals

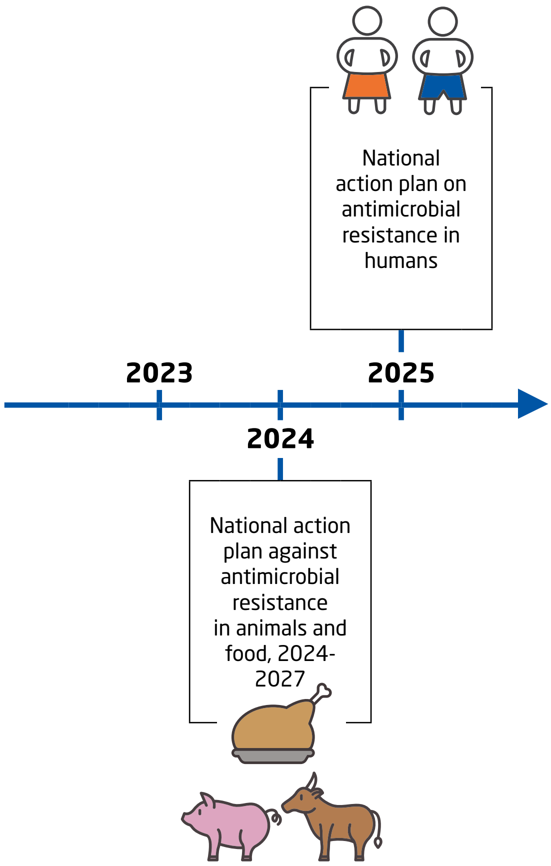
* Veterinary Advisory Service contracts

continued ... Timeline of DANMAP




2013
Differentiated tax on veterinary antimicrobials
2014
Cattle industry target 20% reduction 2012-2018
Mandatory lab. diagnosis when prescribing group-treatment of pigs
2015
Dosages for children included in the antimicro-bial guideline
LA-MRSA plan national target: 15% reduction for pigs by 2018
Pig industry target: 10% reduction 2015-2020
2016
New Yellow Card for pigs with fo-cus on critically important AM
2017
One Health Strategy
Action plan with targets for AMU in humans
Action plan with targets for vet. AMU
Treatment guidelines for horses
2018
Assessment tools included in official AMU guideline for pigs
Advisory Committee on Veterinary Medicines
Legislation about reporting and prevention of CPO
2019
New targets for AMU in pigs 2019-2022 (extended to 2023)
2020
Antimicrobial resistance surveillance of animal pathogens
2021
New **VetStat** database
Revised national action plan for antimicrobial resistance in pro-duction animals and food
2022
Zinc oxide banned for veterinary use
EU directive on limitations on prescription of Veterinary Medicinal Products

continued ... Timeline of DANMAP



10. List of abbreviations

AGP	Antimicrobial growth promoter
AMU	Antimicrobial use
AMR	Antimicrobial resistance
CA	Community-acquired
CPE	Carbapenemase-producing Enterobacterales/Enterobacteriaceae
CPO	Carbapenemase-producing organisms
DAD	Defined Daily Doses per 100 admissions
DADD	Defined Animal Daily Dose
DAPD	Defined Animal Daily Dose per 1,000 animals per day
DCM	Department of clinical microbiology
DDD	Defined Daily Dose
DID	Defined Daily Doses per 1,000 inhabitants per day (DDD/1,000 inhabitants/day)
DTU	Technical University of Denmark
DVFA	Danish Veterinary and Food Administration
HCAI	Health care associated infections
HACO	Health care associated community onset
LA-MRSA	Livestock-associated methicillin-resistant *Staphylococcus aureus*
MiBa	The Danish Microbiology Database
MDR	Multidrug-resistant
MRSA	Methicillin-resistant *Staphylococcus aureus*
PHC	Primary health care
SSI	Statens Serum Institut
VASC	Veterinary advisory service contracts
VMPs	Veterinary medicinal products
VetStat	Danish Register of Veterinary Medicines
VRE	Vancomycin-resistant enterococci
WGS	Whole-genome sequencing
WHO	World Health Organization

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