FINRES-Vet 2021

Finnish Veterinary Antimicrobial Resistance Monitoring and Consumption of Antimicrobial Agents

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RUOKAVIRASTO
Livsmedelsverket • Finnish Food Authority

fimea
Lääkealan turvallisuus- ja kehittämiskeskus
Säkerhets- och utvecklingscentret
för läkemedelsområdet
Finnish Medicines Agency

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Co-funded by
the European Union

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Description

Abstract

Sales of veterinary antibiotics turned to a 5% increase in 2021. The result, however, was the second lowest since the monitoring began. The majority of overall sales consisted of products for individual treatment and the proportion of products for group treatment was roughly over a quarter. The biggest increase in sales was noted for orally administered sulfa-trimethoprim-combination and is partly explained by the increased manufacture of medicated feed for fur animals. Increased sales were also noted for antibiotic tablets for companion animals. Injectable penicillin continued to be the most sold veterinary antibiotic. Sales of critically important antibiotics (HPCIA, WHO) for treatment of animals decreased further and remained very low.

The antibiotic resistance situation in bacteria from animals and food has remained relatively good in Finland. However, in certain bacterial species resistance was detected in moderate or high levels. Therefore, the need remains to further emphasise the preventive measures and prudent use of antibiotics. It is important to follow the Finnish recommendations for the use of antimicrobials in animals.

Among salmonella from food-producing animals and campylobacter from broilers, resistance levels were low. Since 2014, the proportions of fluoroquinolone and tetracycline resistant broiler campylobacter isolates have varied. Among porcine campylobacter, fluoroquinolone resistance has increased. Resistance situation among indicator *E. coli* from pigs has remained good. The prevalence of ESBL/AmpC-producing bacteria in slaughtered pigs increased in 2021 while no ESBL/AmpC-producing bacteria were detected in pork and beef at retail. MRSA bacteria were detected more than previously in fresh pork at retail.

The resistance situation among pathogenic bacteria isolated from food-producing animals remained similar to 2020. Resistance was overall low in bovine and porcine respiratory pathogens as well as in pathogens isolated from broilers. Resistance was still detected most in enterotoxigenic *E. coli* from pigs. Among bacteria isolated from companion animals, the changes in resistance situation were mostly small. The proportion of canine *E. coli* strains resistant to third-generation cephalosporins was the lowest since the start of the monitoring.

Kuvailulehti

Tiivistelmä

Eläinten antibioottien myynti kääntyi vuonna 2021 viiden prosentin kasvuun. Tulos oli kuitenkin toiseksi matalin seurannan aloittamisen jälkeen. Valtaosa antibiooteista annettiin eläinyksilöille, ryhmälääkityksinä annettavien antibioottien osuus oli reilu neljännes. Eniten lisääntyi suun kautta annettavan sulfa-trimetopriimi-yhdistelmän myynti, mikä selittyi muun muassa turkiseläinten lääkerehun valmistuksen lisääntymisellä. Myös seuraeläinten antibioottitablettien myynti lisääntyi. Injektiopenisilliini oli edelleen eniten käytetty eläinten antibiootti. Ihmisten reserviantibioottien myynti (HPCIA, WHO) pieneni edelleen ja oli erittäin vähäistä.

Eläimistä ja elintarvikkeista eristettyjen bakteerien antibioottiresistenssitilanne Suomessa on pysynyt suhteellisen hyvänä. Joillakin bakteerilajeilla resistenssiä kuitenkin esiintyy kohtalaisesti tai yleisesti, joten eläinten antibioottien käyttötarpeen vähentämiseen ja hallittuun antibioottien käyttöön tulee jatkossakin kiinnittää huomiota. Eläimille annettuja mikrobilääkkeiden käyttösuosituksia on tärkeää noudattaa.

Kotimaisista tuotantoeläimistä eristetyillä salmonelloilla ja broilereista eristetyillä kampylobakteereilla resistenssiä todettiin vähän. Vuodesta 2014 alkaen broilereista eristetyillä kampylobakteereilla on todettu vaihtelevasti resistenssiä fluorokinoloneille ja tetrasykliinille. Sikojen kampylobakteereilla fluorokinoloniresistenssi on lisääntynyt. Sioista eristettyjen *E. coli* -indikaattoribakteerien resistenssitilanne on pysynyt hyvänä. ESBL/AmpC-bakteereiden esiintyminen suomalaisissa teurassioissa lisääntyi vuonna 2021, kun taas vähittäismyynnissä olevasta sian- ja naudanlihasta ei todettu ESBL/AmpC-bakteereita lainkaan. MRSA-bakteereita esiintyi tuoreessa vähittäismyynnissä olevassa sianlihassa aiempaa enemmän.

Tuotantoeläinten patogeenien resistenssitilanne pysyi samankaltaisena vuoteen 2020 verrattuna. Resistenssiä todetaan yleisesti ottaen vähän nautojen ja sikojen hengitystietulehduksia aiheuttavissa bakteereissa sekä broilereilta eristetyissä patogeeneissa. Eniten resistenssiä todettiin edelleen sikojen enterotoksisilla *E. coli* -kannoilla. Seura- ja harraste-eläimistä eristettyjen bakteerien resistenssitilanteen muutokset olivat pääasiassa pieniä. Kolmannen polven kefalosporiineille vastustuskykyisten koirien *E. coli* -kantojen osuus oli pienin koko seurantajakson aikana.

Beskrivning

Referat

Försäljningen av antibiotika för djur ökade med fem procent år 2021. Resultatet var ändå näst lägst sedan påbörjandet av uppföljningen. Största delen av antibiotikan gavs till djurindivider och drygt en fjärdedel var gruppläkemedel. Speciellt försäljningen av sulfa-trimetoprim-kombination som administreras oralt ökade och kan till en viss grad förklaras av den ökade tillverkningen av läkemedelsfoder till pälsdjur. Också försäljningen av antibiotikatabletter för sällskapsdjur ökade. Den mest använda antibiotikan var fortfarande penicillin i injektionsform. Försäljningen av de viktigaste kritiskt viktiga antimikrobiella ämnena (HPCIA, WHO) för behandling av djur minskade och var fortsättningsvis mycket låg.

Resistenssituationen hos bakterier som har isolerats från djur och livsmedel är fortvarande relativt god i Finland. Hos vissa bakterier var förekomsten av resistens ändå måttlig eller vanlig. Därför ska uppmärksamhet fortvarande ägnas åt åtgärderna för att minska behovet av att använda antibiotika för djur och för att kontrollera användningen av antibiotika. Det är viktigt att följa rekommendationerna för användning av antimikrobiella medel för djur.

Salmonellabakterier isolerad från finländska livsmedelsproducerande djur och campylobakterier isolerad från slaktkycklingar visade liten resistens. Sedan 2014 har campylobakterieisolater från slaktkycklingar visat sig ha varierande resistens mot fluorokinoloner och tetracyklin. Fluorokinolonresistens i campylobakterier från svin har ökat. Resistenssituationen för E. coli -indikatorbakterier isolerade från svin har varit fortsatt god. Förekomsten av ESBL/AmpC-bakterier i finländska slaktsvin ökade år 2021, medan inga ESBL/AmpC-bakterier hittades i detaljhandeln bland fläsk- och nötkött. MRSA-bakterier fanns i färskt fläsk mer än tidigare.

Resistenssituationen för patogener i produktionsdjur förblev liknande jämfört med 2020. I allmänhet var resistensen låg hos bakterier som orsakar luftvägsinfektioner hos nötkreatur och svin, liksom hos patogener isolerade från slaktkycklingar. Mest resistens hittades fortvarande i enterotoxiska E. coli -stammar från svin. Förändringar i resistenssituationen för patogener isolerade från sällskaps- och hobbydjur var huvudsakligen små. Andelen E. coli -stammar hos hundar som var resistenta mot tredje generationens cefalosporiner var den lägsta under hela uppföljningsperioden.

CONTENTS

Introduction

FINRES-Vet 2021 reports statistics on sales of veterinary antibiotics and antibiotic resistance in bacteria isolated from animals and food. This report covers the latest results from 2021 but includes data also from previous years to enable a follow-up of trends.

FINRES-Vet programme is coordinated by the Finnish Food Authority. Other collaborators are the Finnish Medicines Agency (Fimea) and the University of Helsinki. The Finnish Food Authority coordinates the FINRES-Vet programme and monitors antibiotic resistance in bacteria from food-producing animals. The Finnish Medicines Agency monitors sales of veterinary antibiotics, and Finnish Food Authority the use of feed additives and medicated feeds. The Clinical Microbiology Laboratory of the Faculty of Veterinary Medicine (University of Helsinki) provides antibiotic susceptibility data from companion animals and horses.

In 2021, antibiotic resistance was monitored in zoonotic and indicator bacteria from production animals along with resistance of certain animal pathogens from clinical submission isolated from production and companion animals. An updated resistance monitoring in zoonotic and indicator bacteria in European Union started in 2021 (Commission Implementing Decision (EU) 2020/1729) and it affected also in the mandatory targets, e.g. including the imported meat from third countries.

Monitoring resistance in zoonotic bacteria is important as resistance can transfer between bacteria, animals, and humans, creating a risk also to human health. Resistance in animal pathogens needs monitoring in order to recognise emerging resistance traits, and to indicate effectiveness of antibiotic treatments and whether prudent use guidelines to veterinarians are up to date. However, it must be emphasized that when assessing the overall resistance levels of pathogenic bacteria isolated from clinical cases, data may be biased because the isolates are frequently obtained from uncommonly severe or recurrent infections. The resistance of indicator bacteria in a certain population reflects the selection pressure caused by antibiotic use. Indicator bacteria constitute a major component of intestinal microbiota, and their genomes can also function as a reservoir of resistance genes, which may be transferred to pathogenic bacteria.

FINRES-Vet programme has the following objectives:
- to monitor the consumption of antibiotics used in veterinary medicine,
- to monitor antibiotic resistance in bacteria from major food-producing animals, food, and companion animals,
- to analyse trends in the occurrence of resistant bacteria from animals and food,
- to monitor the emergence of resistant clones and the appearance of new resistance phenotypes in bacteria from the afore-mentioned sources.

During the FINRES-Vet monitoring period which started in 2002, the overall resistance situation in bacteria isolated from animals and food of animal origin in Finland has been favourable. This is probably due to the long history of strict antibiotic policy, and active promotion of health and welfare of food-producing animals i.e. preventive measures. National prudent use guidelines recommend choosing narrow spectrum antibiotics and individual treatment whenever possible (Evira, 2016). Overall sales of veterinary antibiotics in Finland have been low, the sales in 2021 being the second lowest since reporting began. Penicillin is the most used antibiotic and majority of antibiotics are given to individual animals. However, increase in resistance in some zoonotic bacteria and certain animal pathogens has been observed in recent years. This highlights the importance of long-term monitoring of antibiotic resistance and indicates that preventive measures need further improvement and the prudent use guidelines should be strengthened.

1 Sales of antibiotics for use in animals

1.1 Changes in animal population

Changes in the number of food-producing animals from 2020 to 2021 were relatively small. The number of pigs remained stable. The number of cattle continued to decrease slowly, while a slow annual increase in the number of poultry also continued (Figure 1). Details on the number of holdings, live animals, and meat and milk production are presented in Appendix 1. The number of livestock and the number of animals slaughtered are used for calculating Population Correction Unit (PCU) which takes into account both number of animals and their weights. Since 2012, the PCU has decreased by 5% from 514 to 491 (thousand tons).
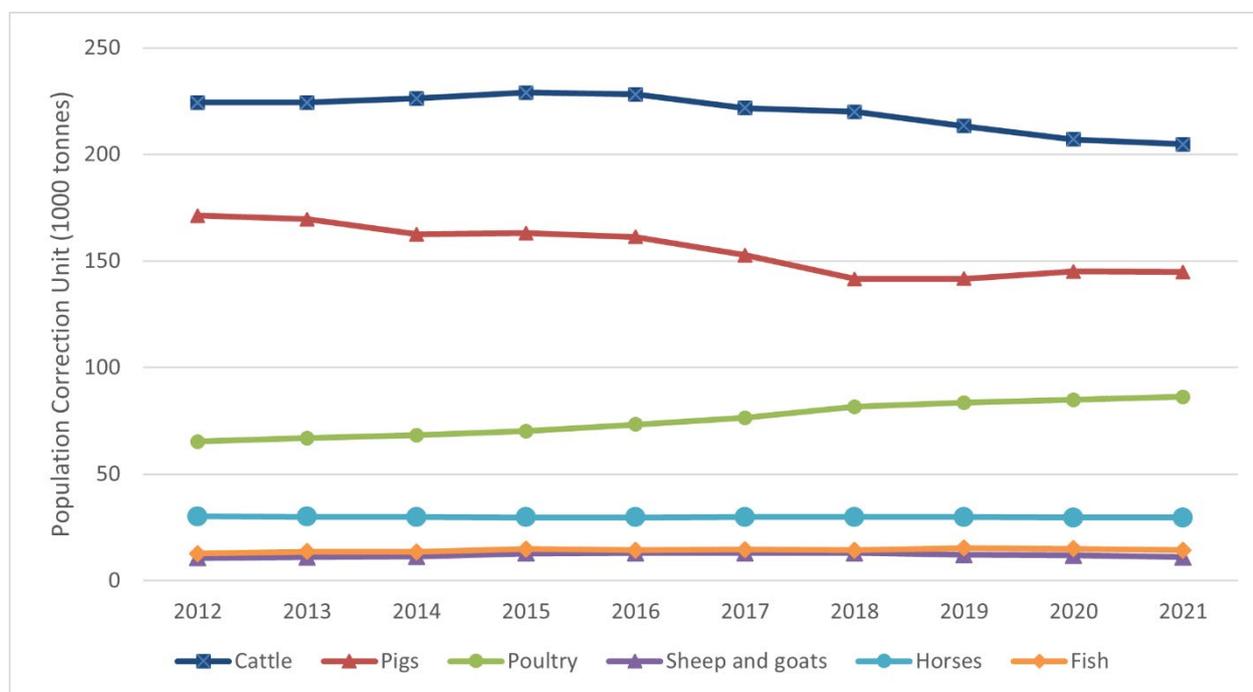
Figure 1. *Changes in food-producing animal population in Finland in 2012–2021, PCU (1000 tonnes). Detailed data on the PCU of food-producing animals in a tabulated form is presented in Appendix 1.*

Regarding the number of companion animals, Statistics Finland estimated that the number of dogs and cats in 2016 was about 700 000 and 600 000, respectively. More current data are not available. It has been estimated that the number of companion animals has increased during the COVID-19 pandemic. Numbers of fur animals have changed quite a lot during the last decade (FIFUR Statistics, 2022). The numbers were at highest about 4.7 million animals in 2015 equaling to estimated 30 tonnes of live animals. After that the numbers have decreased and there were about 2.2 million animals in 2021. This equals to estimated 14 tonnes of live animals.

1.2   Sales of antibiotics for treatment of animals

1.2.1 Background

Finnish Medicines Agency Fimea monitors the sales of veterinary antibiotics based on statistics obtained from pharmaceutical wholesalers. Sales data are available since 1995. This report includes data for 2011–2021. For a review of data for 1995–2010, see the FINRES-Vet reports covering the corresponding years.

In 2010, the data collection method was harmonised with the protocol of the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project. The data also covers sales figures for veterinary antibiotics that are used according to a special license (exemption from marketing authorisation i.e., veterinary antibiotic products obtained from other Member States and permitted to be released for consumption for use in specified animal species). In 2021 their proportion was approximately 8 % of the overall sales.

Sales data are presented as kg active ingredient for overall sales and sales by different pharmaceutical forms (i.e. injectables, antibiotics administered orally, intramammaries and tablets). For intramammaries, sales of tubes per cow is also reported. It should be noted that the dosing of antibiotics varies between and within antibiotic classes, and between animal species treated. In addition, sales expressed as kg active ingredient does not take into account changes in animal populations and hence when observing such sales data, it is important to compare trends in sales of antibiotics to the same class over a longer period of time.

To compare changes in annual sales of antibiotics, the data should be in proportion to the population of animals in the given period. In this report, a population correction unit (PCU) is used. One PCU corresponds approximately to one kg and represents an estimate of livestock population and slaughtered animals each year. PCU is strictly a technical unit and covers the population of major food-producing species. PCU was developed within the ESVAC project, and a detailed description is available in 'Trends in the sales of veterinary antimicrobial agents in nine European countries: Reporting period 2005–2009' (EMA, 2011). Population adjusted sales, mg active ingredient per PCU (mg/PCU) are presented in this report only for the EU indicators of veterinary antibiotics applicable in Finland. Consumption is reported for overall sales, sales of fluoroquinolones and 3rd generation cephalosporins (ECDC, EFSA and EMA, 2017). PCU adjusted data does not include tablets, as they are almost exclusively used in companion animals and only estimates of the number of dogs and cats in Finland are available. Therefore, sales of tablets cannot be adjusted to the population of companion animals, and they are presented in a separate figure, as kg active ingredient.

1.2.2 Overall sales (kg active ingredient)

Overall sales of veterinary antibiotics turned to a 5% increase in 2021 (Figure 2, Table 23 in Appendix 2). The 2021 sales, 9378 kg, however, is the second lowest ever reported in Finland. An increase was noted especially in sales of sulfonamide-trimethoprim combinations, penicillins and amphenicols, whereas sales of eight antibiotic classes decreased.
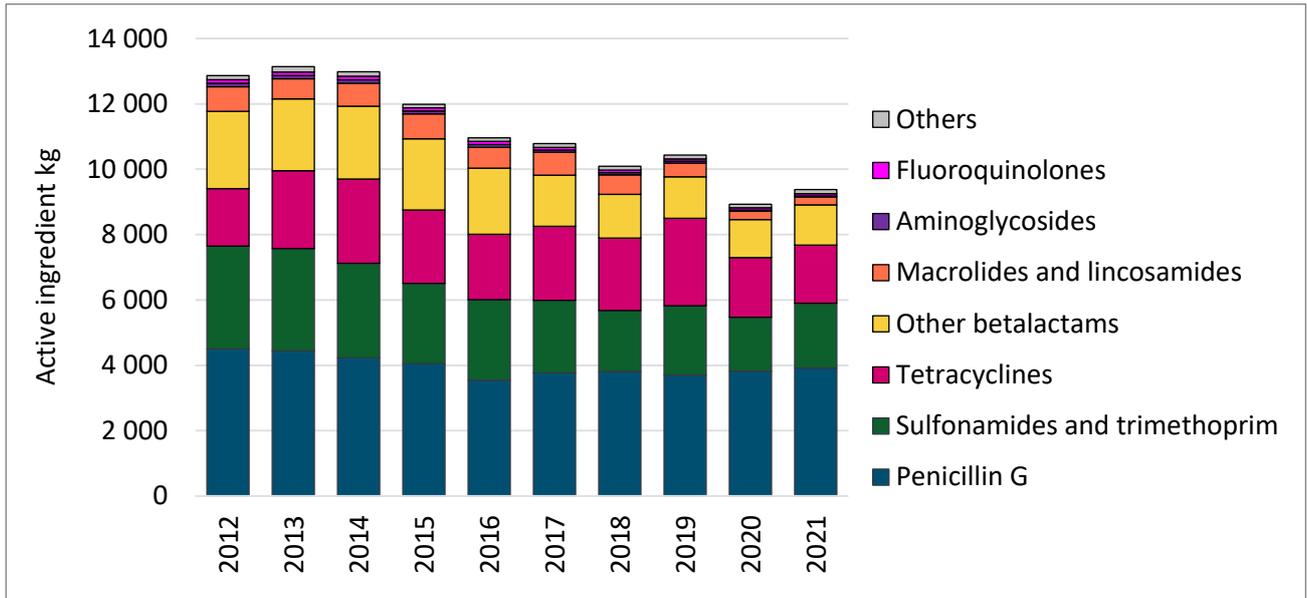
Figure 2. Overall sales (kg active ingredient) by class in 2012–2021. Other betalactams = aminopenicillins, cephalosporins and cloxacillin. Others = pleuromutilines, amphenicol and imidazole derivatives. For detailed data in tabulated form see Appendix 2.

Over two thirds (72%) of antibiotics sold (in kg active ingredient) in 2021 were pharmaceutical forms intended for the treatment of individual animals (injectables, tablets, oral pastes and intramammary products). The proportion of products applicable for group treatment (premixes, oral powders, and oral solutions) was less than one third of the overall sales (Figure 3).
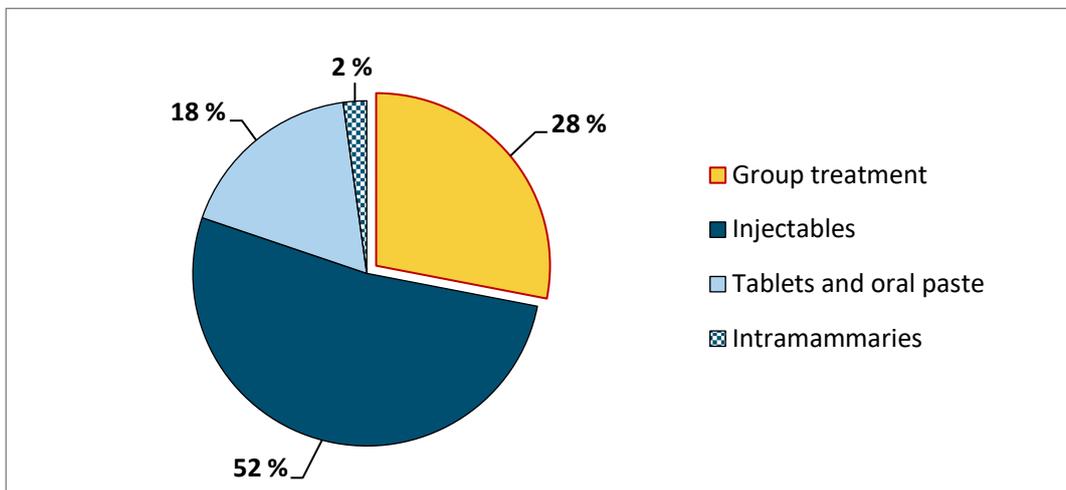
Figure 3. Sales of veterinary antibiotics by form in 2021. Group treatment: premixes, oral solutions, and oral powders.

The most-sold antibiotics were benzylpenicillin (42%), sulfonamide-trimethoprim combinations (21%) and tetracyclines (19%) (Figure 2). Of the antibiotic classes considered as critically important in human medicine (HPCIA) by both EMA and WHO (EMA 2019 and WHO 2019), only two are authorised for use in animals in

Finland, namely fluoroquinolones, and 3rd generation cephalosporins. The proportion of sales for these remained low to extremely low (fluoroquinolones 0.7% and 3rd generation cephalosporins 0.002%). WHO also considers macrolides as HPCIA, their sales for use in animals in Finland was low (2 % of the overall sales).

1.2.3 Sales based on route of administration (kg active ingredient)

Over half of the antibiotics sold (52 %) were products administered as injections to animals (Figure 3, Table 24 in Appendix 2). Narrow spectrum penicillin continues to be the most sold injectable (75%) followed by tetracyclines (12%) and aminopenicillins (4%) (Figure 4A). Overall sales of injectables remained stable from 2020 to 2021, but some changes were seen between antibiotic classes. From 2020 to 2021, sales of penicillin G increased by 4% and sales of aminopenicillins by 18%. Sales of other injectable antibiotic classes decreased or remained almost unchanged.

In 2021, sales of orally administered antibiotics turned to a 10% increase after dropping 27% in 2020. The 2020-2021 change is almost entirely due to an increase in sales of sulfonamide-trimethoprim combinations (+27%) which also continues to be the most-sold orally administered antibiotic (41% of orally administered antibiotics) followed by tetracyclines (28%) and aminopenicillins (17%) (Figure 4B). Other orally administered antibiotic classes with increased sales in 2021 were amphenicols, aminopenicillins and fluoroquinolones whereas decreased sales were noted for six antibiotic classes. Zero-sales were reported for orally administered aminoglycosides and pleuromutilins, for both of which a decreasing trend has been observed already for several years (Table 25 in Appendix 2).

Overall, during the last decade sales of orally administered antibiotics peaked in 2013–2014 and have since decreased by 40%. Marked fluctuations noted in recent years in sales of orally administered antibiotics were to a great extent related to the changes in the amount of medicated feed manufactured for treatment of fur animals (FINRES-Vet 2020). In 2020–2021, this proportion decreased clearly but altogether almost one third of the increased sales of orally administered antibiotics in 2021 were due to increased manufacture of medicated feed for fur animals, especially sulfonamide-trimethoprim combination (Table 26 in Appendix 2 and Finnish Food Authority, 2022).
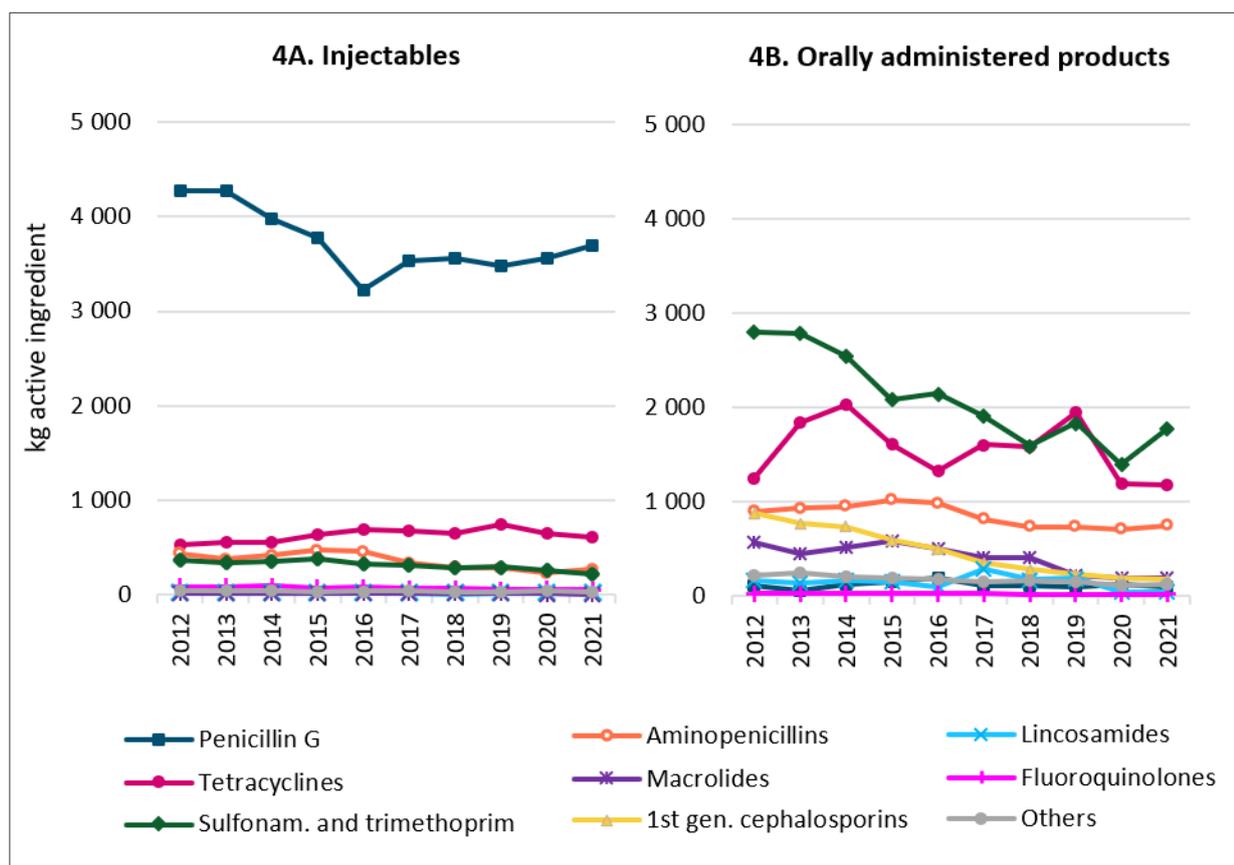
Figure 4A and 4B. *Trends in sales of injectable veterinary antibiotics (4A) and sales of orally administered veterinary antibiotics (4B) in 2012–2021. Other injectables = amphenicols, aminoglycosides and cephalosporins, Other oral products = amphenicols, aminoglycosides, pleuromutilins and imidazole derivatives. For detailed data in tabulated form see Appendix 2.*

Veterinary antibiotic tablets are almost solely used for treatment of companion animals. Their sales more than halved during the last decade but from 2020 to 2021 a 10% increase is observed (Figure 5). This was mainly due to increased sales of aminopenicillins, which in practice consists of sales of aminopenicillin and clavulanic acid combination (> 95% of sales of aminopenicillins). The remainder of the increased sales seems to be related to the better availability of veterinary antibiotic tablets. There was a disruption in availability of sulfonamide-trimethoprim combination which was eventually covered trough special license arrangements. The two new antibiotic classes of antibiotics (tetracyclines and imidazole derivatives) also added to the increased availability. It is likely that for these three antibiotic classes human medicinal products were prescribed earlier, however their sales are not captured with the current methodology. Sales of 1st generation cephalosporin tablets continued to decrease.

Updated statistics on the number of companion animals are not available but it has been estimated that the number of dogs and cats has increased in recent years (Chapter 1.1). To note is that this report contains only sales of veterinary antibiotic products. Data collection of the volume of human antibiotics prescribed and used for companion animals would require an electronic prescribing or other data collection system, which is currently not available for veterinarians in Finland. Legislation, however, requires veterinarians to

choose a veterinary medicinal product if such is available, and therefore the amount of human antibiotics prescribed for treatment of animals is assumed to be modest.
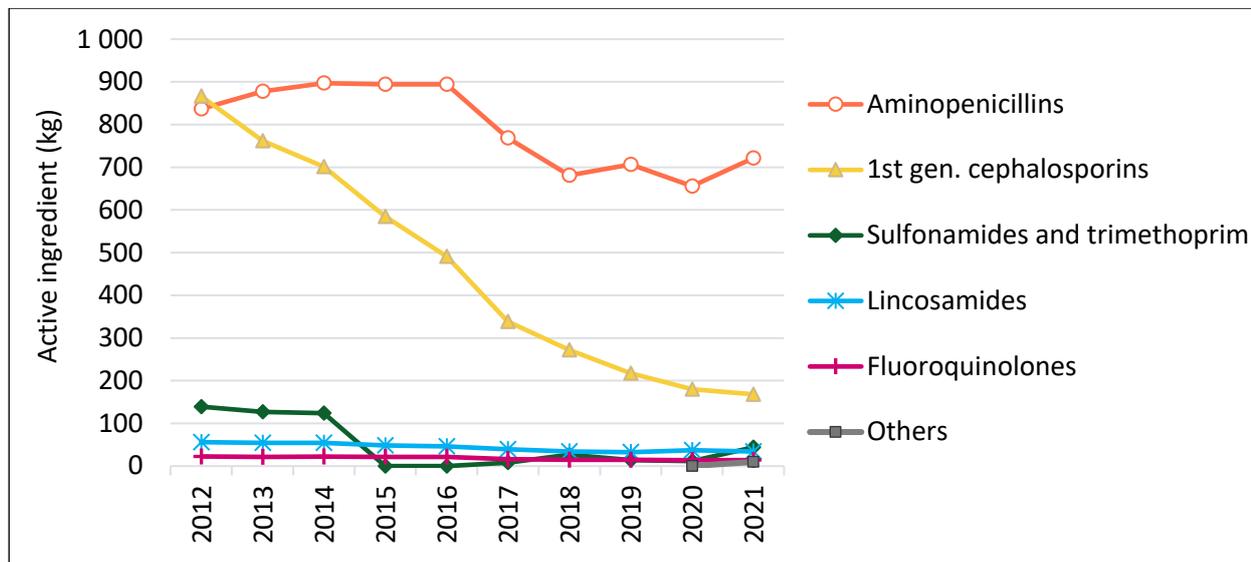
Figure 5. Sales of antibiotic tablets to companion animals (kg active ingredient) by class. Note that sulfonamide and trimethoprim combination tablets were withdrawn from the market in 2015 and are currently available only on special license. Others include tetracyclines and imidazole derivatives (sales approximately 10 kg in 2021).

For the first time during the monitoring of veterinary antibiotic consumption in Finland, less intramammary antibiotic products were sold for use during the lactation phase compared to use for the dry period (Figure 6.). A decade ago, approximately two intramammary tubes per cow were sold annually for treatment during the lactation period, whereas in 2021 the sales have reduced to less than one tube per cow. Instead, the sales of dry period intramammary products have remained relatively stable, although a modest upward trend in recent years can be observed.

Almost 80% of the tubes used during the lactation phase contained narrow spectrum penicillin and the proportion of cloxacillin was 20%. Correspondingly, the most-used antibiotic in intramammaries for the dry period was penicillin (50%) followed by cloxacillin (29%) and aminoglycosides (22%) (Table 26, Appendix 2).
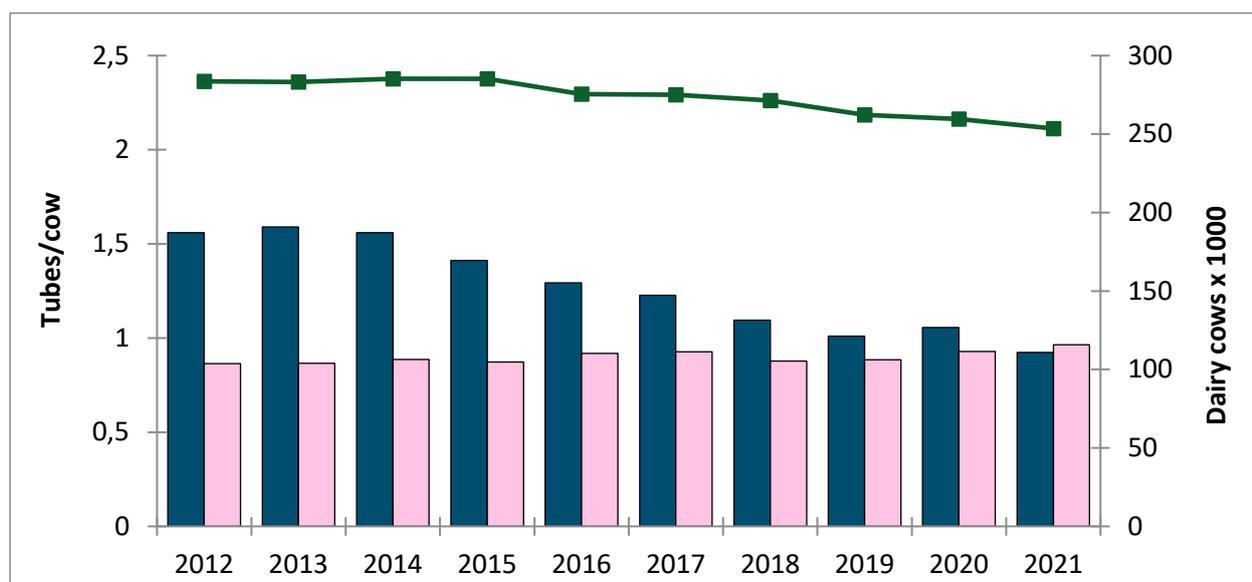
Figure 6. Antibiotics for intramammary use per cow during lactation period (blue column) and for dry cow period (pink column) and the number of dairy cows (green curve).

1.2.4 EU-indicators of antibiotic consumption in food-producing animals (mg/PCU)

ECDC, EFSA and EMA have jointly established a list of indicators to assist EU Member States in assessing their progress in reducing the use of antibiotics and occurrence of antibiotic resistance in both humans and food-producing animals (ECDC, EFSA and EMA 2017). Of these, overall sales of veterinary antibiotics, sales of 3rd generation cephalosporins and sales of fluoroquinolones measured in mg/PCU are applicable for food-producing animals in Finland.

All other pharmaceutical forms except tablets are included in the calculations of population corrected sales in food-producing animals, as veterinary tablets are almost exclusively used for the treatment of companion animals. It should be noted that injectable antibiotic products are often authorised for both food-producing and companion animals. It has, however, been estimated that the volume of use of injectable antibiotics in companion animals is minor (measured as kg active ingredient) and therefore such sales can be included in the overall sales for food-producing animals (EMA, 2021). For certain injectable antibiotic classes that in Finland are only allowed for use in companion animals and foals, e.g. 3rd generation cephalosporins, their inclusion results in an overestimation of the use in food-producing animals.

Overall sales of veterinary antibiotics for food-producing animals increased by 5% (0.8 mg/PCU) from 2020 to 2021. Nevertheless, 2021 sales 17.1 mg/PCU was the second lowest observed since the beginning of population corrected reporting (Table 1). Sales of 3rd generation cephalosporins continued to decrease (- 9%) and remained at an extreme low level (0.0004 mg/PCU). Sales of fluoroquinolones remained stable at a low level (0.11 mg/PCU).

Table 1. *EU-indicators of antibiotic consumption in food-producing animals (mg/PCU) in Finland. Note that sales of tablets have been excluded as they are used almost exclusively to companion animals.*

Sales (mg/PCU)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Overall sales	21.3	21.9	21.8	20.1	18.2	18.9	18.1	19.1	16.1	17.1
Fluoroquinolones	0.16	0.16	0.18	0.14	0.15	0.12	0.13	0.10	0.11	0.11
3rd generation cephalosporins[1]	0.029	0.016	0.016	0.014	0.006	0.001	0.001	0.0005	0.0004	0.0004

[1] Since 2017, sales of 3rd generation cephalosporins only for treatment of foals and companion animals.

For decades, the strategic policy in Finland has been to reduce the need for antibiotic treatment by eradicating infectious animal diseases, using efficient biosecurity measures and herd health programmes to achieve good animal health. If antibiotics, however, are needed, they should be used in accordance with the national prudent use guidelines (available since 1996, updated three times, most recently in 2016). In 2014, a requirement of susceptibility testing before using the highest priority critically important antibiotics was added to the national legislation. An overview of the strategic actions implemented since 1949 is available at the Finnish Food Authority website (Finnish Food Authority, 2021b).

1.3   Sales of coccidiostats and antibiotic feed additives for use in animals

Finnish Food Authority monitors the annual consumption of feed additives by collecting data from feed manufacturers. In 2021, only coccidiostats monensin sodium, narasin and nicarbazin were used as prophylactic anti-parasitic agents mainly in broiler and turkey production. The overall use of coccidiostats decreased slightly from 2016 to 2018 but has since increased again in 2019, 2020 and 2021 (Table 2). Compared to the year 2011, the use of coccidiostats has increased approximately 50%.

Table 2. *The use of coccidiostats, antibiotic and other substances in feed in Finland 2012–2021 (kg active substance/year).*

Substance	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Coccidiostats										
Decoquinate	0	0	0	0	0.1	0	0	0	0	0
Diclazuril	0	0	0	0	0	0.8	0.5	0.04	0	0
Lasalocid sodium	0	0	0	0	0	0	1 336	0	0	0
Madmuramycin ammonium	0	0	0	0	0	0	0	0	0	0
Monensin sodium	7 300	4 614	6 677	12 640	15 373	14 693	5 097	13 979	14 710	14 767
Narasin	6 567	9 626	9 022	5 478	5 026	4 918	13 152	6 535	6 084	6 428
Nicarbazin	0	0	0	0	0	0	0	0	0	117
Salinomycin	0	0	0	0	0	0	0	0	0	0
Robenidine hydrochloride	0	0	0	0	0	0	0	0	0	0
Antibiotic substances										
Avoparcin	0	0	0	0	0	0	0	0	0	0

Substance	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Flavomycin	0	0	0	0	0	0	0	0	0	0
Carbadox	0	0	0	0	0	0	0	0	0	0
Olaquindox	0	0	0	0	0	0	0	0	0	0
Other substances										
Amprolium (and ethopabate)	0	0	0	0	0	0	0	0	0	0
Dimetridazole	0	0	0	0	0	0	0	0	0	0
Nifursol	0	0	0	0	0	0	0	0	0	0
Total	13 867	14 240	15 699	18 117	20 399	19 613	18 585	20 514	20 795	21 312

2 Antibiotic resistance in zoonotic bacteria

2.1 Salmonella from food-producing animals and domestic food

The prevalence of salmonella in cattle, pigs, and poultry as well as in meat and eggs was monitored through the national Salmonella control programme (Ministry of Agriculture and Forestry, MAF, Decrees 1030/2013; 1037/2013; 134/2012). From May 2021, salmonella control programme was amended (MAF Decree on zoonoses 316/2021). The objective of the salmonella control programme is to keep the annual incidence of salmonella contamination among food-producing animals at a maximum of 1%, and in meat and eggs at a maximum of 1% or from May 2021, at a maximum of 0.5%. Salmonella has been rare in food-producing animals and foods of animal origin in Finland. Salmonella isolates from the control programme are tested for antibiotic susceptibility and included in the FINRES-Vet programme.

In 2021, the susceptibility panel of the tested antibiotics changed: amikacin was added, and the concentration ranges changed for a few of the other antibiotics. Details of the susceptibility testing as well as correspondences between the verbal descriptions of the resistance levels and the actual percentage categories are described in Appendix 3.

In 2021, 50 salmonella isolates from food-producing animals were tested for susceptibility. Most of the isolates originated from cattle (n=27) and pigs (n=16). Seven isolates originated from *Gallus gallus*. The most common serotypes were *S*. Typhimurium (n=11), *S*. Altona (n=9), *S.* Enteritidis (n=5) and *S*. Uganda (n=5). Other serotypes are shown in Appendix 4.

Resistance in salmonella from food-producing animals was overall low (Table 3). Monophasic *S*. Typhimurium was found in three cases from pigs and two of them showed a typical multidrug resistance pattern (ampicillin, sulfamethoxazole, trimethoprim). *S*. Kentucky was discovered from three cattle farms, and two of them were resistant to six antibiotics (ampicillin, ciprofloxacin, gentamicin, nalidixic acid, sulfamethoxazole, tetracycline). Other resistant isolates obtained in 2021 were *S*. Typhimurium (resistant to tetracycline and trimethoprim) from one laying hen farm, and *S*. Typhimurium (resistant to ampicillin, sulfamethoxazole, tetracycline, and trimethoprim) from three cattle farms.

In four cases, minimum inhibitory concentration (MIC) values for colistin were >2 µg/mL which is the cut-off value used in EU resistance monitoring according to Commission implementing Decision (EU) 2020/1729. Two of these isolates were *S*. Typhimurium (MIC values 4 and 16) and two *S*. Enteritidis (MIC value 8). Both *S*. Typhimurium isolates were subjected to whole-genome sequencing but no known resistance mechanisms for colistin were found. Currently, European Committee on Antimicrobial Susceptibility Testing (EUCAST) gives no epidemiological cut-off for salmonella except for a tentative cut-off for *Salmonella* Dublin (>16 µg/mL).

Resistance situation of salmonella isolated from Finnish food-producing animals has been very favourable for a long time and multidrug resistance has not been common. However, multidrug resistant salmonella has been detected in food-producing animals in Finland now in four consecutive years (Figure 7).

Table 3. *Distribution of MICs for Salmonella enterica from food-producing animals in 2021 (n=50).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)															
			0.015	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512
Amikacin[1]	0.0	0.0–7.1									100								
Ampicillin	14.0	7.0–26.2							64.0	22.0					14.0				
Azithromycin	0.0	0.0–7.1								4.0	38.0	58.0							
Cefotaxime[1]	0.0	0.0–7.1					94.0	6.0											
Ceftazidime	0.0	0.0–7.1					66.0	28.0	6.0										
Chloramphenicol	0.0	0.0–7.1										100							
Ciprofloxacin	4.0	1.1–13.5	34.0	62.0								4.0							
Colistin[2]	-	-							80.0	12.0	2.0	4.0	2.0						
Gentamicin	4.0	1.1–13.5						90.0	6.0			2.0	2.0						
Meropenem[1]	0.0	0.0–7.1		82.0	18.0														
Nalidixic acid	4.0	1.1–13.5									94.0	2.0				4.0			
Sulfamethoxazole[3]	14.0	7.0–26.2											52.0	32.0	2.0				14.0
Tetracycline	16.0	8.3–28.5								82.0	2.0				16.0				
Tigecycline[4]	-	-					76.0	16.0	6.0	2.0									
Trimethoprim[1]	8.0	3.2–18.8					28.0	42.0	20.0	2.0				8.0					

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance for *Salmonella enterica*. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1]Tentative ECOFF. [2]For colistin, a tentative EUCAST ECOFF is available only for *Salmonella* Dublin (>16), and because the natural susceptibility for colistin differs between serovars, no interpretation of resistance is shown. [3]For sulfamethoxazole, no EUCAST ECOFF is available, therefore, a cut-off value of >256 µg/mL is used (dashed vertical line) for resistance monitoring purposes. [4]For tigecycline, EUCAST ECOFF is used for resistance monitoring purposes.

Figure 7. The number of sensitive and resistant salmonella isolates from food-producing animals in Finland in 2012–2021. The number of isolates tested each year are in brackets. Antibiotic classes included in the analysis: aminoglycosides, beta-lactams, phenicols, quinolones, sulfonamides, tetracyclines and diaminopyrimidines (trimethoprim).

2.2 Campylobacter from food-producing animals

In 2021, *Campylobacter jejuni* and *C. coli* from broilers were obtained from the national Campylobacter programme and *C. coli* was isolated from pigs in the Finnish Food Authority. In 2021, the susceptibility panel of the tested antibiotics changed: chloramphenicol and ertapenem were added, and nalidixic acid and streptomycin were removed. To allow comparison to previous years, antibiotic susceptibility figures showing complete susceptibility and resistance to one, two or more antibiotic classes were analysed based on the susceptibility results of four antibiotics that remained the same before and after 2021. Also, in 2021 it became mandatory for the first time to report susceptibility results for *C. coli* from broilers in the EU (Commission implementing decision (EU) 2020/1729).

2.2.1 *Campylobacter jejuni* and *Campylobacter coli* from broilers

Within the national Campylobacter control programme of broilers in 2021, 144 *C. jejuni* and five *C. coli* isolates were detected and tested for susceptibility. Of the *C. jejuni* isolates, four (2.8%) were resistant to ciprofloxacin and one (0.7%) to tetracycline (Table 4). Of the five *C. coli* isolates tested, three (60%) were resistant to ciprofloxacin. Resistance to the other studied antibiotics was not detected in either species.

Antibiotic resistance in *C. jejuni* from broilers has been monitored yearly since 2003. The proportions of resistant *C. jejuni* isolates have been quite stable until the year 2013 and the occurrence of resistant isolates has been mainly at a low level (Figure 8). However, the occurrence of quinolone resistance in *C. jejuni* has been more common in 2014, 2016, 2018 and 2019. In 2014 and 2016, quinolone resistance

was commonly accompanied with tetracycline resistance whereas in 2018 and 2019, tetracycline resistance was not observed. In 2020 and 2021, the proportions of quinolone and tetracycline resistant isolates were again at a low level. The proportion of isolates resistant to erythromycin and gentamicin has remained low or non-existent throughout the monitoring period. The percentage of isolates susceptible to all the studied antibiotic classes has varied between 75% and 100%, with the lowest percentages in 2014 and 2018 paralleling the highest occurrences of quinolone resistance (Figure 9). Multidrug resistance to the tested antibiotics has not been detected. For *C. coli* from broilers, the number of isolates was too low to make any conclusions.
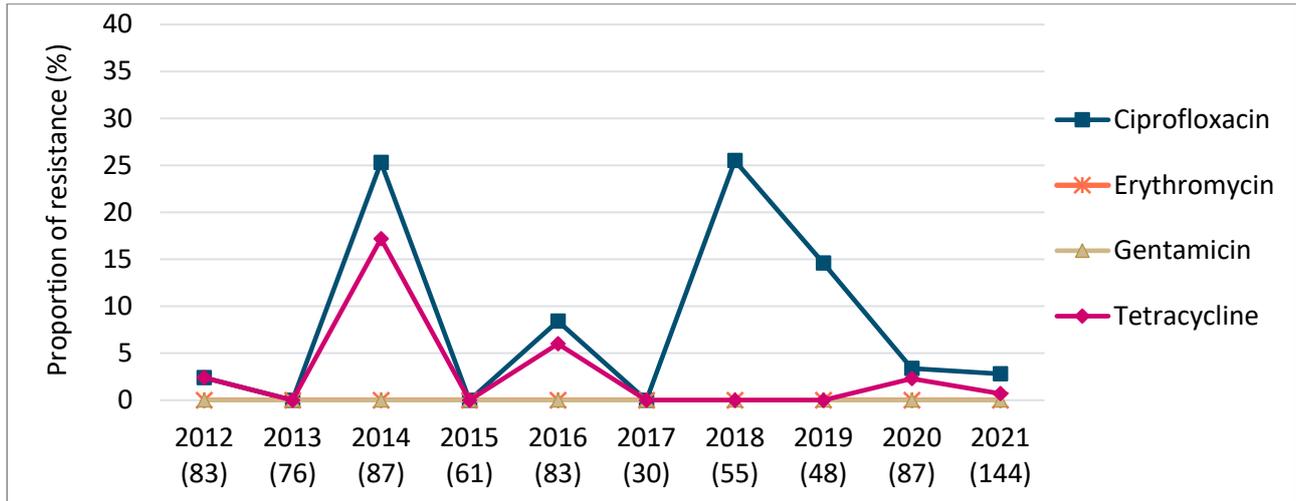
Figure 8. *The proportions of resistant Campylobacter jejuni isolates from broilers at slaughter in Finland between the years 2012 and 2021. The number of isolates tested each year are in brackets.*
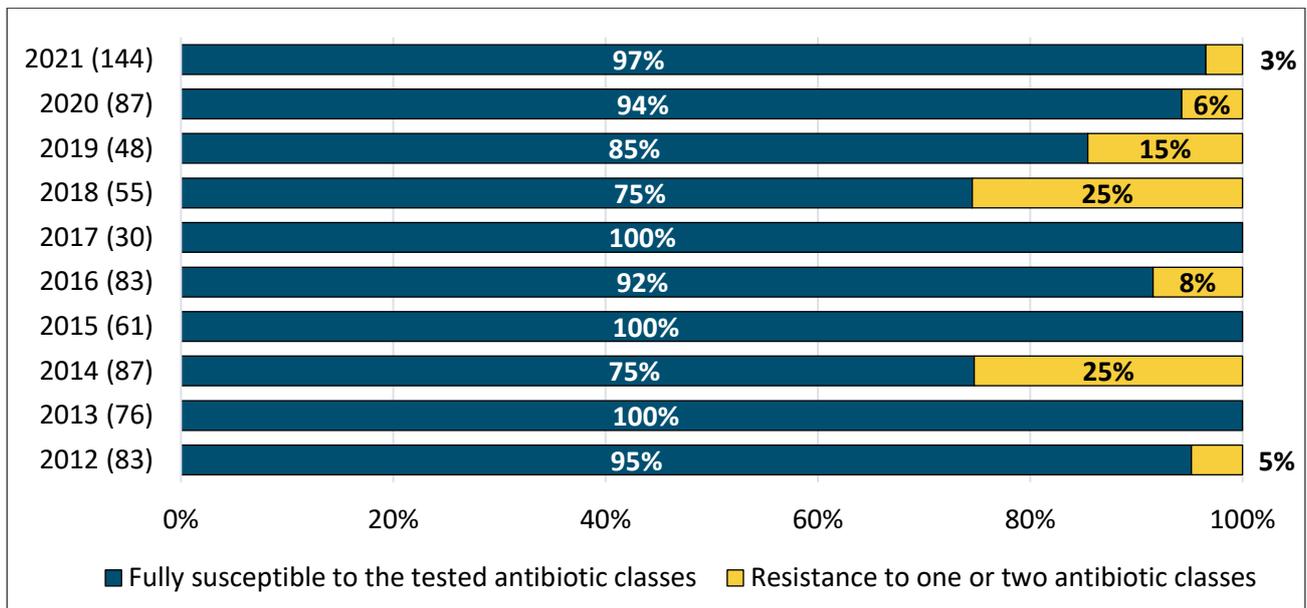
Figure 9. *Antibiotic susceptibility of Campylobacter jejuni isolated from broilers at slaughter in Finland between the years 2012 and 2021. The number of isolates tested each year are in brackets. Antibiotic classes included in the analysis: aminoglycosides (gentamicin), fluoroquinolones (ciprofloxacin), macrolides (erythromycin), and tetracyclines.*

Table 4. *Distribution of MICs for Campylobacter jejuni from broilers in 2021 (n=144).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)													
			0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512
Chloramphenicol	0.0	0.0–2.6					96.5	3.5								
Ciprofloxacin	2.8	1.1–6.9	92.4	4.2	0.7			0.7	2.1							
Ertapenem[1]	-	-	97.2	2.8												
Erythromycin	0.0	0.0–2.6					99.3	0.7								
Gentamicin	0.0	0.0–2.6		20.1	72.9	6.9										
Tetracycline	0.7	0.1–3.8			97.9	1.4						0.7				

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1]For ertapenem, no EUCAST ECOFF was available.

Table 5. *Distribution of MICs for Campylobacter coli from pigs in 2021 (n=170).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)													
			0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512
Chloramphenicol	0.0	0.0–2.2					49.4	48.2	2.4							
Ciprofloxacin	33.5	0.27–0.4	57.1	9.4				4.1	21.8	7.6						
Ertapenem[1]	-	-	87.1	9.4	3.5											
Erythromycin	0.6	0.1–3.3				81.2	16.5	1.8					0.6			
Gentamicin	0.0	0.0–2.2		0.6	24.1	75.3										
Tetracycline	0.0	0.0–2.2		0.6	98.2	1.2										

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1]For ertapenem, no EUCAST ECOFF was available

2.2.2 *Campylobacter coli* from pigs

In 2021, 170 *C. coli* isolates from swine caecal samples, collected at slaughter, were studied for antibiotic resistance. Of these, 57 (34%) were resistant to ciprofloxacin and one (0.6%) to tetracycline (Table 5). No gentamicin, erythromycin or chloramphenicol resistant isolates were detected.

C. coli have been isolated in the FINRES-Vet monitoring programme from pigs every third or fourth year since 2004. The proportion of fluoroquinolone resistant isolates has been moderate to high between 2010 and 2021 while the proportions of resistant isolates for other antibiotic classes has remained at a low level or nonexistent (Figure 10). During the same time, the proportions of fully susceptible isolates have varied between 66% and 82% being at its lowest in the most recent study year 2021 (Figure 11). This is almost solely due to the increase in fluoroquinolone resistance.
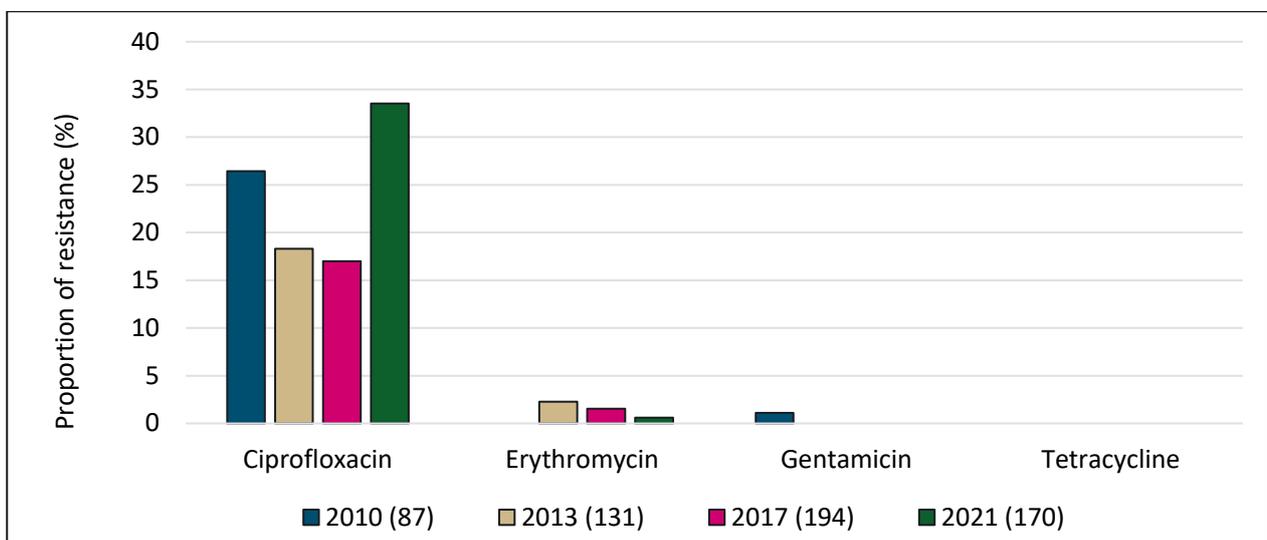
Figure 10. *Resistance in Campylobacter coli isolated from pigs at slaughter in Finland in 2010–2021. The number of isolates tested each year are in brackets.*
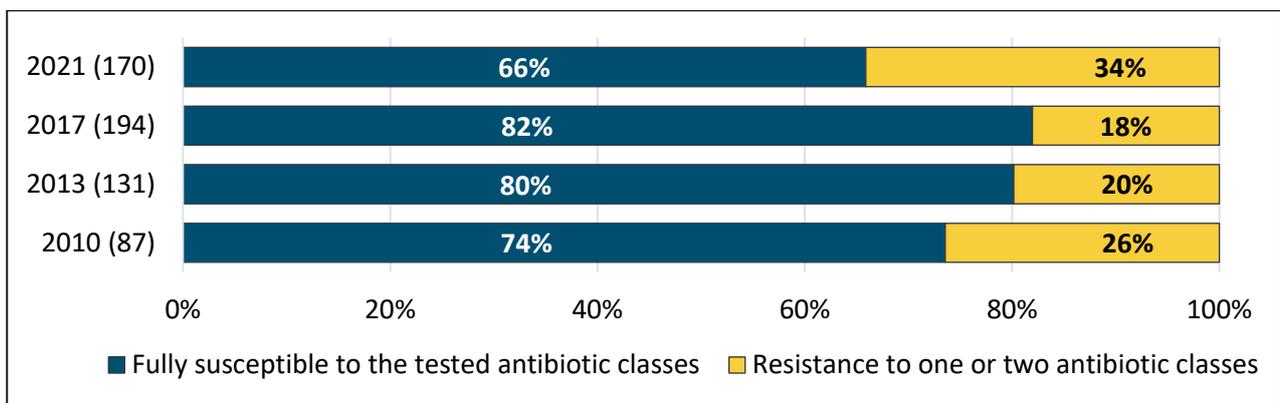
Figure 11. *Antibiotic susceptibility of Campylobacter coli isolated from pigs at slaughter in Finland in 2010–2021. The number of isolates tested each year are in brackets. Antibiotic classes included in the analysis: aminoglycosides (gentamicin), fluoroquinolones (ciprofloxacin), macrolides (erythromycin), and tetracyclines.*

2.2.3 *Campylobacter jejuni* from fur animals

Campylobacter spp. are isolated from fur animals as part of diarrhea examination, mostly from farmed foxes and farmed minks. *Campylobacter jejuni* infections in fur animals are treated with antibiotics and these bacteria also pose a risk to the farmers. Data from years 2020 and 2021 were combined as the number of tested isolates was rather low in both years.

In 2020–2021, resistance to nalidixic acid was most commonly detected (22.7%) (Table 6). The occurrence of quinolone and tetracycline resistance increased from 2019 being 17.9% in 2020–2021. Over the years from 2016 to 2021, occurrence of isolates resistant against tetracycline has varied from high to low levels while occurrence of fluoroquinolone (ciprofloxacin) resistance has remained relatively stable at moderate level. Resistance against erythromycin has been detected only in one isolate in 2021, and resistance against gentamicin has not been detected.

Table 6. *Distribution of MICs for Campylobacter jejuni from fur animals in 2020–2021 (n=28).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)											
			0.12	0.25	0.5	1	2	4	8	16	32	64	128	>128
Ciprofloxacin	17.9	7.9–35.6	78.6	3.6					10.7	7.1				
Erythromycin	3.6	0.6–17.7				96.4							3.6	
Gentamicin	0.0	0.0–12,6		10.7	67.9	17.9	3.6							
Nalidixic acid[1]	22.7	10.1–43.4						77.3				4.5	18.2	
Streptomycin[1]	0.0	0.0–14.9			9.1	13.6	59.1	18.2						
Tetracycline	17.9	7.9–35.6			82.1							3.6	14.3	

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1]n=22
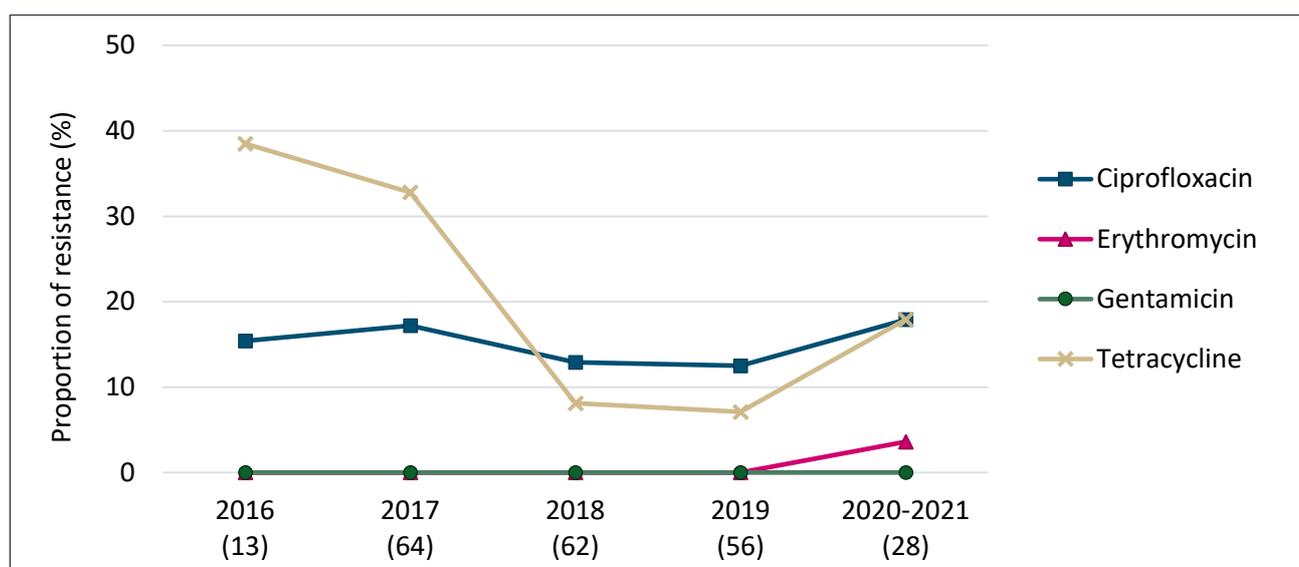
Figure 12. *The proportions of resistant Campylobacter jejuni isolates from fur animals in Finland between the years 2016 and 2019. Numbers of isolates tested each year are in brackets.*

3   Screening for ESBL-, AmpC- and carbapenemase-producing *Escherichia coli* from food-producing animals and meat

Screening of extended-spectrum beta-lactamase producing *E. coli* from food-producing animals and meat thereof is part of the harmonised monitoring in all EU member states (2013/652/EU and from 2021, (EU) 2020/1729). In Finland, these bacteria are screened from broilers, cattle, and pigs, as well as meat thereof, targeting pigs, pork, and beef in 2021. In 2021, it became mandatory in EU to monitor also fresh meat originating from third countries according to (EU) 2020/1729. Additionally, liners from the transport boxes of imported broiler parental flocks and eggs, and turkey parental flocks for meat production as well as of imported chicken parental flocks for egg production are screened annually. In 2020 and 2021, a small survey of ESBL screening was also conducted among fur animals. The details of the methodology are described in Appendix 3.

3.1   ESBL/AmpC- and carbapenemase-producing *E. coli* in pigs and meat from bovines and pigs

In 2021, extended-spectrum beta-lactamase (including AmpC beta-lactamase) producing *E. coli* were screened with selective isolation method from pig caecal samples (n=307) collected at slaughterhouses, fresh pork (n=313) and beef (n=308) samples collected at retail, and imported beef (n=1) at the border control post.

In 2021, the prevalence of ESBL- or AmpC-producing *E. coli* in slaughter pigs was 6.5%, AmpC being the predominant phenotype (Table 7). Carbapenemase-producing *E. coli* was not detected. Compared to the previous monitoring years 2015, 2017 and 2019, the prevalence of ESBL/AmpC-producing *E. coli* in pigs has increased (Table 7, Figure 13). Molecular analysis of the isolates (n=20) revealed beta-lactamase genes bla_{TEM-1B} (n=2), $bla_{CTX-M-15}$ (n=2) and bla_{CMY-2} (n=1). In addition, *ampC* promoter region mutations C-42T (n=16) and T-32A (n=1) were detected. ESBL/AmpC phenotypes corresponded with the molecular findings.

Most of the meat samples (pork, beef) collected from retail shops have been of domestic origin. In 2021, no ESBL-, AmpC- or carbapenemase-producing *E. coli* were isolated from pork or beef. ESBL/AmpC-producing *E. coli* have been very rare in pork and beef in all the studied years 2015, 2017, 2019 and 2021 (Figure 13, Figure 14). ESBL/AmpC-producing *E. coli* in cattle were last monitored in 2020 when these bacteria were found in 3.1% of the samples (Figure 14). Carbapenemase-producing *E. coli* was not detected in any of the meat samples.

In 2021, imported meat samples originating from third countries were included in the sampling according to (EU) 2020/1729. Samples of fresh meat from pigs were not analysed in 2021 because no consignments were imported to Finland. Of the six consignments of fresh bovine meat imported to Finland, one was sampled and analysed. ESBL, AmpC or carbapenemase-producing *E. coli* were not detected in any of the three sub-samples analysed.

Table 7. Results of the specific screening of ESBL-, AmpC- and carbapenemase-producing E. coli in food-producing animals and meat in 2015, 2016, 2017, 2019, 2020 and 2021.

Year	Sampling stage	Nr of samples	Nr (%) of ESBL[1]	Nr (%) of AmpC[1]	Nr of CP-EC[2]	% ESBL/AmpC
Pigs						
2021	at slaughter	307	2 (0.7%)	18 (5.9%)	0	6.5%
2019	at slaughter	288	1 (0.3%)	6 (2.1%)	0	2.4%
2017	at slaughter	299	1 (0.3%)	7 (2.3%)	0	2.7%
2015	at slaughter	306	1 (0.3%)	8 (2.6%)	0	2.9%
Pork						
2021	at retail	313	0 (0%)	0 (0%)	0	0%
2019	at retail	306	0 (0%)	0 (0%)	0	0%
2017	at retail	301	0 (0%)	0 (0%)	0	0%
2015	at retail	303	0 (0%)	1 (0.3%)	0	0.3%
Cattle						
2020	at slaughter	295	4 (1.4%)	5 (1.7%)	0	3.1%
2016[3]	at slaughter	233	0(0%)	3 (1.3%)	0	1.3%
Beef						
2021	at BCP[4]	1	0 (0%)	0 (0%)	0	0%
2021	at retail	313	0 (0%)	0 (0%)	0	0%
2019	at retail	297	2 (0.7%)[5]	0 (0%)	0	0.7%
2017	at retail	302	0 (0%)	0 (0%)	0	0%
2015	at retail	300	0 (0%)	0 (0%)	0	0%

[1] based on phenotypic characterization, see appendix 3.

[2] CP-EC, carbapenemase-producing *Escherichia coli*

[3] CP-EC were screened from 204 samples.

[4] border-control post

[5] both findings were of non-domestic origin
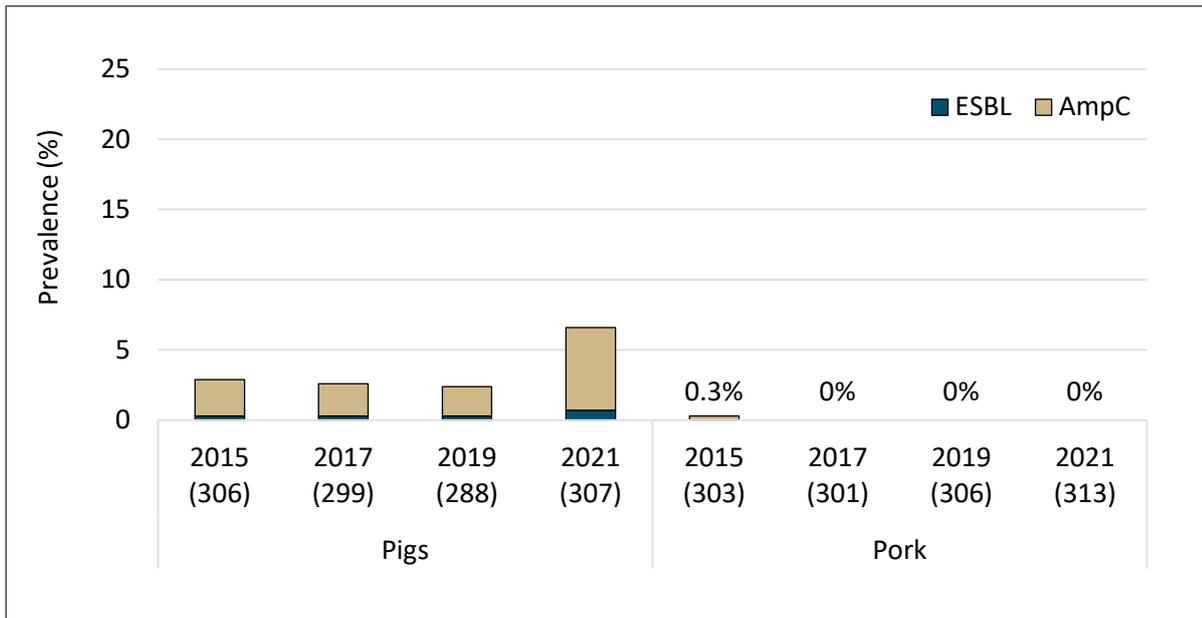
Figure 13. *Proportion of ESBL- and AmpC-producing E. coli in pigs and pork in 2015, 2017, 2019 and 2021. The number of samples tested each year are in brackets.*
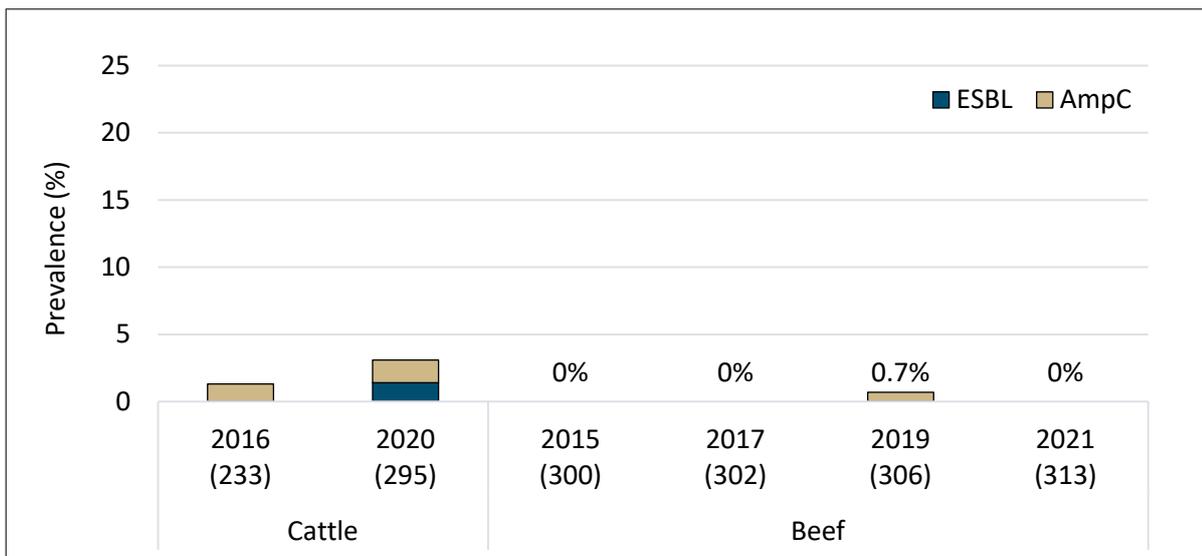
Figure 14. *Proportion of ESBL- and AmpC-producing E. coli in cattle in 2016 and 2010, and in beef in 2015, 2017, 2019 and 2021. The number of samples tested each year are in brackets.*

3.2 ESBL/AmpC- and carbapenemase-producing *E. coli* in imported poultry flocks

In 2021, liners of transport boxes of 35, six and three imported poultry flocks intended for broiler meat, turkey meat and chicken egg production chains, respectively, were screened for ESBL/AmpC- and carbapenemase-producing *E. coli* (Table 8). This represents the majority of poultry flocks imported to Finland (see details in Appendix 3).

No ESBL/AmpC-producing *E. coli* were found in the imported poultry flocks in 2021. During the years 2014–2021, the proportion of positive flocks has fluctuated from 0 to 39% for the imported broiler production chain, and from 0 to 75% for the chicken egg production chain. Between 2018 and 2021, ESBL/AmpC-producing *E. coli* were found only from one imported poultry flock and thus the situation is very favourable. Carbapenemase-producing *E. coli* have not been detected.

Table 8. Results of the specific screening of ESBL- and AmpC-producing E. coli in liners from the transport boxes of imported poultry flocks and eggs in 2014–2021.

Imported poultry flocks	2014	2015	2016	2017	2018	2019	2020	2021
For broiler meat production								
Nr of sampled flocks	37	54	62	37	42	38	34	35
Nr of ESBL positive flocks	1	1	0	0	0	0	0	0
Nr of AmpC positive flocks	3	9	24	8	0	0	0	0
Nr (%) of ESBL/AmpC positive flocks	4 (11%)	10 (19%)	24 (39%)	8 (22%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
For turkey production								
Nr of sampled flocks	5	6	5	4	5	5	4	6
Nr of ESBL positive flocks	0	0	0	0	0	0	0	0
Nr of AmpC positive flocks	0	0	0	0	0	0	0	0
Nr (%) of ESBL/AmpC positive flocks	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
For egg production								
Nr of sampled flocks	6	4	3	4	5	3	5	3
Nr of ESBL positive flocks	1	1	0	0	0	0	0	0
Nr of AmpC positive flocks	3	2	0	3	0	0	1	0
Nr (%) of ESBL/AmpC positive flocks	4 (67%)	3 (75%)	0 (0%)	3 (75%)	0 (0%)	0 (0%)	0 (20%)	0 (0%)

3.3 ESBL/AmpC- and carbapenemase-producing *E. coli* in fur animals

ESBL-, AmpC- and carbapenemase-producing *E. coli* were screened from domestic, farmed fur animals between 2020 and April 2021. Samples originated from animals sent for pathological-anatomical diagnosis or for corona virus screening. Altogether, samples were taken from animals originating from 81 different holdings (57 holdings with minks, 13 holdings with blue foxes and 11 holdings with raccoon dogs). Details of the methodology are described in Appendix 3. One phenotypically confirmed AmpC *E. coli* was found in 2020 and one phenotypically conformed ESBL *E. coli* in 2021.

4   Screening for MRSA from food-producing animals and meat

Methicillin resistant *Staphylococcus aureus* is not regularly monitored in animals or food in Finland. Previously, specific surveys have been carried out mostly in pigs and pork. In 2020 and 2021, MRSA was screened from fur animals and in 2021 in pork. The details of the methodology are described in Appendix 3.

4.1   MRSA in fur animals

MRSA was screened from domestic, farmed fur animals between March 2020 and April 2021. Samples originated from animals sent for pathological-anatomical diagnosis or for corona virus screening. Altogether, samples were taken from animals originating from 81 different holdings (57 holdings with minks, 13 holdings with blue foxes and 11 holdings with raccoon dogs). MRSA was not found in any of the samples.

4.2   MRSA in pork

In 2021, 206 fresh pork samples taken at retail shops were analysed for MRSA. Of all the samples tested, 199 samples were of domestic origin. MRSA was found in 26 (12.6%) samples. Twenty-five of these were of domestic origin. Five different *spa* types were detected, t034 (n=14), t2741 (n=9), t728 (n=1), t4677 (n=1) and t899 (n=1, non-domestic meat). All *spa* types except t728 belong to the livestock-associated clonal complex (CC) 398. The most common *spa* types t034 and t2471 have been found in pigs in Finland while *spa* types t728 and t4677 have not been detected previously in pigs or pork in Finland. Compared to the previous surveys in 2015 and 2017, an increasing trend can be observed in pork at retail (Figure 15). In 2017, MRSA was found in 6% of the fresh pork samples investigated and in 2015 in 3%. This may partly be explained by the more sensitive one-step enrichment method replacing the two-step enrichment method used in the previous surveys.
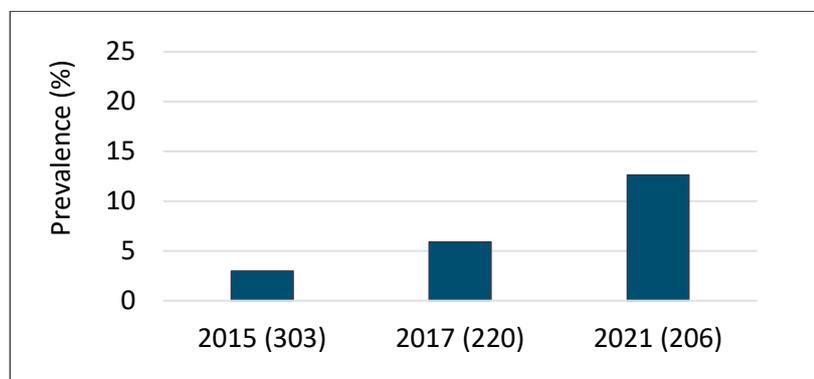
Figure 15. *Prevalence (%) of MRSA in fresh pork at retail in 2015, 2017 and 2021. In 2015 and 2017, the same two-step enrichment method was used while in 2021, the more sensitive one-step enrichment method was used. The number of samples tested each year are in brackets.*

5 Antibiotic resistance in animal pathogens from food-producing animals

Animal pathogens isolated from food-producing animals included in this report are from swine, bovine, and broiler clinical cases. The reported pathogens from pigs are *E. coli* and *Brachyspira pilosicoli* from porcine enteritis, and *Actinobacillus pleuropneumoniae* from respiratory diseases. From bovines, the respiratory pathogens *Pasteurella multocida, Mannheimia haemolytica* and *Histophilus somni* are reported. From broilers, *E. coli* from colibacillosis, and *Staphylococcus aureus* from arthritis and tenosynovitis are reported. Details of sampling, isolation procedures and susceptibility testing are described in Appendix 3.

5.1 *Escherichia coli* from pig enteritis

Escherichia coli isolates from pig enteritis cases were obtained from faecal or post-mortem samples submitted to Finnish Food Authority. All isolates were confirmed by PCR to be enterotoxigenic. Altogether, 35 *E. coli* isolates from 20 farms were included. However, the results are not representative of the whole Finnish pig enteritis *E. coli* population due to the low number of isolates. Furthermore, at least part of the isolates is likely to originate from farms with diarrheal problems and higher than average antibiotic usage. The MIC distributions and the resistance percentages using epidemiological cut-off values are given in Table 9. As before, resistance was commonly detected against ampicillin, fluoroquinolones, tetracycline, streptomycin, as well as sulfamethoxazole, trimethoprim, and their combination. In 2021, resistance to chloramphenicol was low and no resistance to florfenicol was detected. Also, no resistance against colistin or gentamicin has been detected between 2016 and 2021. Resistance against 3rd generation cephalosporins (according to the epidemiological cut-off values) was detected in five isolates from three farms, from which all were phenotypically AmpC. No ESBL-producers were found.

An upward trend in resistance levels against most antibiotics can be seen between 2016 and 2021 (Figure 16). The proportion of multidrug resistance varies annually (Figure 17). Whether this rise in resistance levels for several substances is due to a low number of strains tested and is therefore just a matter of consequence or the resistance situation in pig farms truly is slowly worsening, the results of year 2021 are concerning. More attention should be paid on investigating the true resistance levels of *E. coli* causing porcine postweaning enteritis.

In summary, resistance was commonly detected against all antibiotic classes that can be used to treat *E. coli* infections in pigs (sulfonamide-trimethoprim, tetracycline, aminopenicillins and fluoroquinolones). Attention should be paid to the fact that enteritis in pigs can be caused by multidrug-resistant *E. coli*. This emphasizes the importance of diagnostic samples to determine the farm-specific resistance profiles of enterotoxigenic *E. coli*. To avoid further selection of antibiotic resistance, focus should be aimed to minimize the need for antibiotic treatments and only efficient drugs should be used in the treatment of *E. coli* diarrhea in pigs.
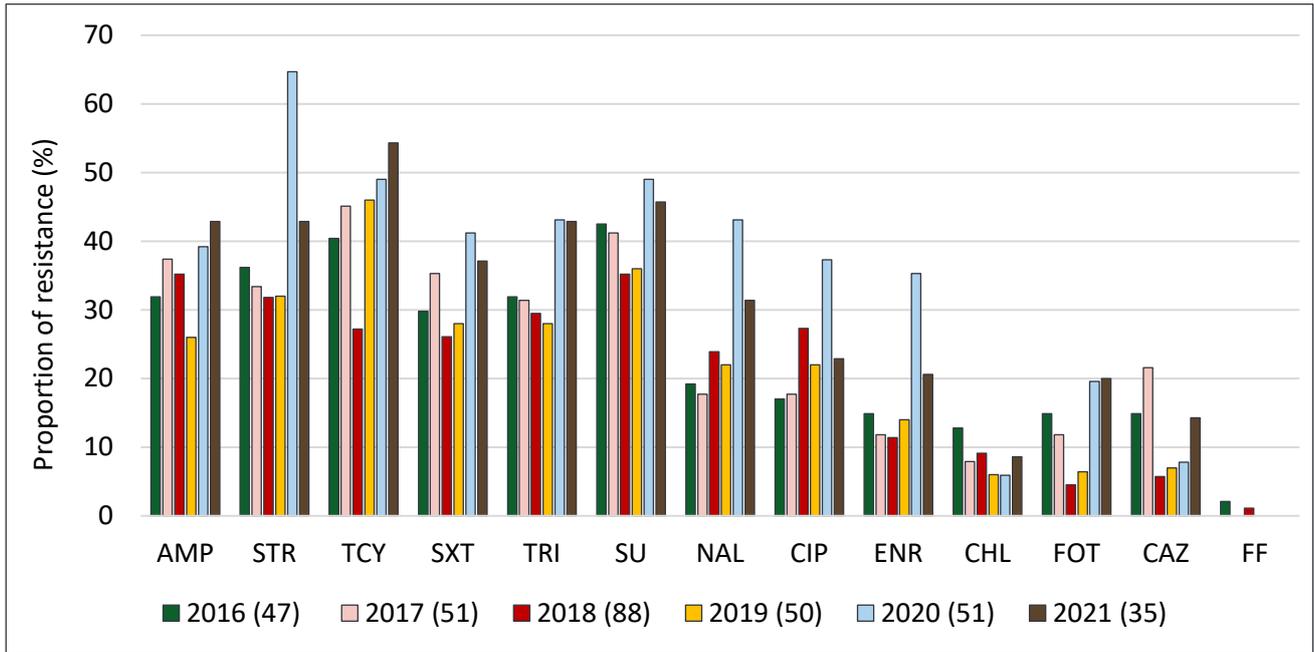
Figure 16. Resistance to tested antibiotics in 2016–2021, epidemiological cut-off values. The number of isolates tested each year are in brackets.

AMP, ampicillin; STR, streptomycin, TCY, tetracycline; SXT, trimethoprim-sulfamethoxazole; TRI, trimethoprim, SU, sulfamethoxazole; NAL, nalidixic acid; CIP, ciprofloxacin; ENR; enrofloxacin; CHL, chloramphenicol; FOT, cefotaxime; CAZ, ceftazidime; FF, florfenicol
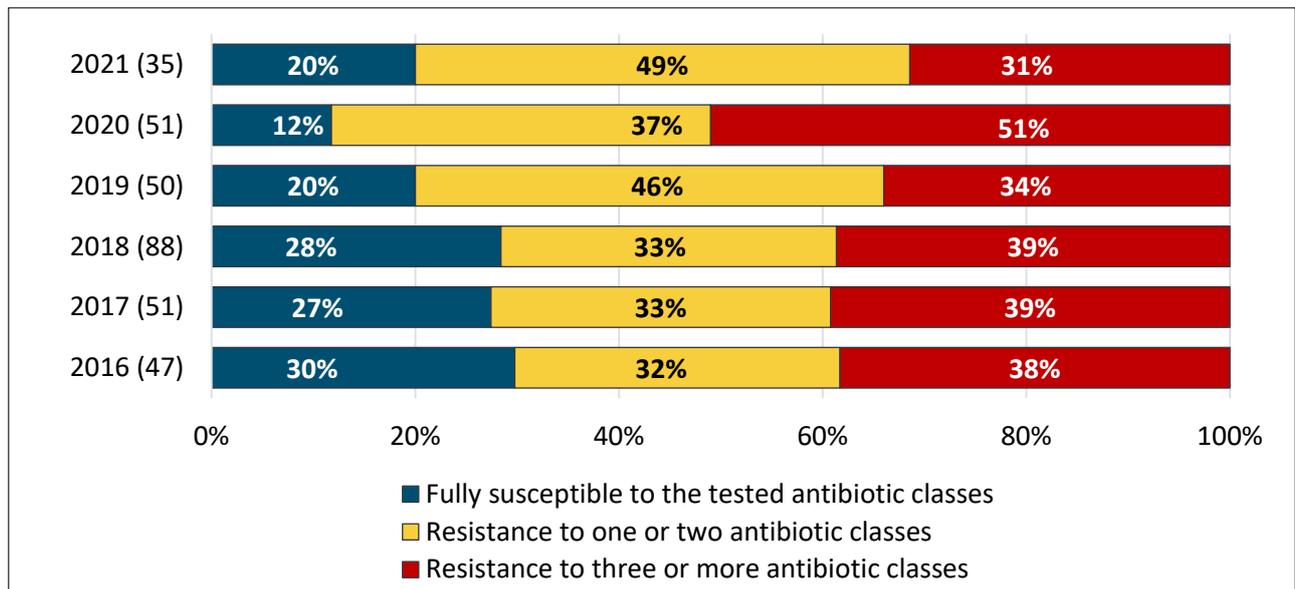
Figure 17. The proportions of multidrug resistant E. coli isolates from porcine enteritis in 2016–2021, epidemiological cut-off values used. The number of isolates tested each year are in brackets. Antibiotic classes included in the analysis: aminoglycosides, aminopenicillins, 3rd generation cephalosporins, amphenicols, polymyxins, fluoroquinolones, sulfonamides, tetracyclines and diaminopyrimidines (trimethoprim).

Table 9. *Distribution of MICs for Escherichia coli from porcine enteritis in 2021 (n=35). Resistance percentage is the proportion of resistance calculated with epidemiological cut-off values.*

Substance	%R	95% C.I.	0.015	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	1024	>1024
Ampicillin	42.9	28.0–59.1							5.7	11.4	37.1	2.9	2.9	22.9	17.1					
Cefotaxime	20.0	10.0–40.0			42.9	34.3	2.9	11.4	8.6											
Ceftazidime	14.3	6.3–29.0					71.4	14.3	14.3											
Chloramphenicol	8.6	3.0–22.4									42.9	40.0	8.6	5.7	2.9					
Ciprofloxacin	22.9	12.1–39.0	20.0	40.0	8.6	8.6	14.3													
Colistin	0.0	0.0–9.9							97.1	2.9										
Enrofloxacin[1]	20.6	10.0–40.0			70.6	8.8	20.6													
Florfenicol	0.0	0.0–9.9									48.6	42.9	8.6							
Gentamicin	0.0	0.0–9.9						91.4	5.7	2.9										
Nalidixic acid	31.4	18.6–48.0									65.7	2.9		5.7	17.1	8.6				
Streptomycin	42.9	28.0–59.1									37.1	20.0		8.6	34.3					
Sulfamethoxazole[2]	45.7	30.5–61.8									2.9	45.7	5.7							45.7
Tetracycline	54.3	38.2–69.5							17.1	28.6					8.6	22.9	22.9			
Trimethoprim	42.9	28.0–59.1					31.4	17.1	8.6					42.9						
Trim/sulfa[3]	37.1	23.2–53.7						60.0	2.9			37.1								

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1] n=34. [2] No EUCAST ECOFF is available, therefore, a cut-off value of >64 µg/mL is used (double vertical line) for resistance monitoring purposes. [3] Differs from EUCAST ECOFF. Concentration of trimethoprim given, tested with sulfamethoxazole in concentration ratio of 1:20.

5.2 *Actinobacillus pleuropneumoniae* from respiratory diseases of pigs

A. pleuropneumoniae is the most important respiratory pathogen in growing pigs in Finland. In 2021, altogether 27 isolates from 22 farms were tested for antibiotic susceptibility. All obtained isolates were included. Clinical breakpoints (CLSI, 2020) were used to evaluate decreased susceptibility (Table 10). Between 2016 and 2021, no significant changes in the MICs for the tested substances can be seen. In contrast to other years, in 2021 one stain was resistant to penicillin and all tested strains were susceptible to oxytetracycline. Each year the number of tested isolates has been rather small.

Table 10. *Distribution of MICs for Actinobacillus pleuropneumoniae from pigs in 2021 (n=27).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)										
			0.12	0.25	0.5	1	2	4	8	16	32	64	>64
Florfenicol	0.0	0.0-12.5		92.6			3.7	3.7					
Ceftiofur	0.0	0.0-12.5		96.3	3.7								
Penicillin[1]	3.7	0.7-18.3	11.1	70.4	14.8					3.7			
Oxytetracycline	0.0	0.0-12.5			100								
Tiamulin	0.0	0.0-12.5							59.3	40.7			
Tulathromycin	0.0	0.0-12.5						7.4	11.1	59.3	22.2		

Bold vertical lines indicate clinical breakpoints for susceptibility (left vertical line) and resistance (right vertical line). Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration.
[1] clinical breakpoints not available, breakpoints for ampicillin used instead

5.3 *Brachyspira pilosicoli* from pigs

There are no standardised breakpoints established for *Brachyspira pilosicoli* from pigs. As a guide for the choice of antibiotic for treatment of spirochaetal diarrhoea, clinical breakpoints of >0.5 mg/L for tiamulin, >32 mg/L for tylosin, >4 mg/L for tylvalosin and >2 mg/L for lincomycin were used in Finland in 2021. With these breakpoints, no resistance was detected against tiamulin (compared to 5% in 2020) whereas 22% (24% in 2020) of the isolates were resistant to tylosin, 22% (24% in 2020) to lincomycin and 22% (10% in 2020) to tylvalosin (Table 11). Resistance in *B. pilosicoli* has overall been at the same level from 2015 to 2021, although the number of isolates tested each year has been too small to draw any definite conclusions.

Table 11. *Distribution of MICs for Brachyspira pilosicoli from pigs in 2021 (n=23).*

Substance	Distribution (%) of MICs (mg/L)													
	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	>128
Doxycycline			91.3				8.7							
Lincomycin					65.2	8.7	4.3		4.3	13.0	4.3			
Tiamulin		73.9	17.4	4.3	4.3									
Tylosin						26.1	26.1	13	4.3	8.7	8.7			13.0
Tylvalosin			8.7	26.1	30.4	21.7		4.3		8.7				
Valnemulin	77.3	18.2		4.5										

No clinical breakpoints available. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration.

5.4 *Histophilus somni*, *Pasteurella multocida* and *Mannheimia haemolytica* from bovine respiratory disease

One isolate per submission (and from each compartment if more than one was sampled) and per bacterial species was selected for susceptibility testing. Clinical breakpoints (CLSI, 2020) were used to evaluate decreased susceptibility. All tested isolates were susceptible to ceftiofur and florfenicol.

Histophilus somni isolates, obtained from 19 farms, were fully susceptible in 2021 (Table 12). Between 2016 and 2020, decreased susceptibility was detected only against oxytetracycline (from 7% to 11%) but the resistant isolates have all originated from the same calf-rearing farm. *H. somni* was not isolated in this farm in 2021.

Table 12. *Distribution of MICs for Histophilus somni from bovine respiratory disease in 2021 (n=19).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)										
			0.12	0.25	0.5	1	2	4	8	16	32	64	>64
Ceftiofur	0.0	0.0–16.8		100									
Enrofloxacin	0.0	0.0–16.8	100										
Florfenicol	0.0	0.0–16.8		100									
Oxytetracycline	0.0	0.0–16.8			100								
Penicillin	0.0	0.0–16.8	100										
Tulathromycin	0.0	0.0–16.8					15.8	47.4	31.6	5.3			

Bold vertical lines indicate clinical breakpoints for susceptibility (left vertical line) and resistance (right vertical line). Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration.

In 2021, *Pasteurella multocida* isolates were obtained from 139 farms and on 137/139 (98%) of these farms, isolates were fully susceptible. Nearly all *P. multocida* isolates investigated were fully susceptible, with only two isolates being resistant to oxytetracycline (separate farms) and one isolate to tulathromycin. Intermediate susceptibility was not noted for any antibiotic. Since 2016, resistance has been low overall

among *P. multocida* from bovine respiratory diseases (Figure 18). Resistance has most commonly been detected against oxytetracycline with a proportion between one and eight percent. The MIC distributions of different antibiotics for *P. multocida* isolated in 2021 are shown in Table 13.

Table 13. Distribution of MICs for Pasteurella multocida from bovine respiratory disease in 2021 (n=186).

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)										
			0.12	0.25	0.5	1	2	4	8	16	32	64	>64
Ceftiofur	0.0	0.0–2.0		100									
Enrofloxacin	0.0	0.0–2.0	100										
Florfenicol	0.0	0.0–2.0		53.2	46.8								
Oxytetracycline	1.1	0.3–3.8			81.7	3.8	13.4			1.1			
Penicillin	0.0	0.0–2.0	99.5	0.5									
Tulathromycin	0.5	0.1–3.0				45.2	37.1	16.7	0.5				0.5

Bold vertical lines indicate clinical breakpoints for susceptibility (left vertical line) and resistance (right vertical line). Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration.
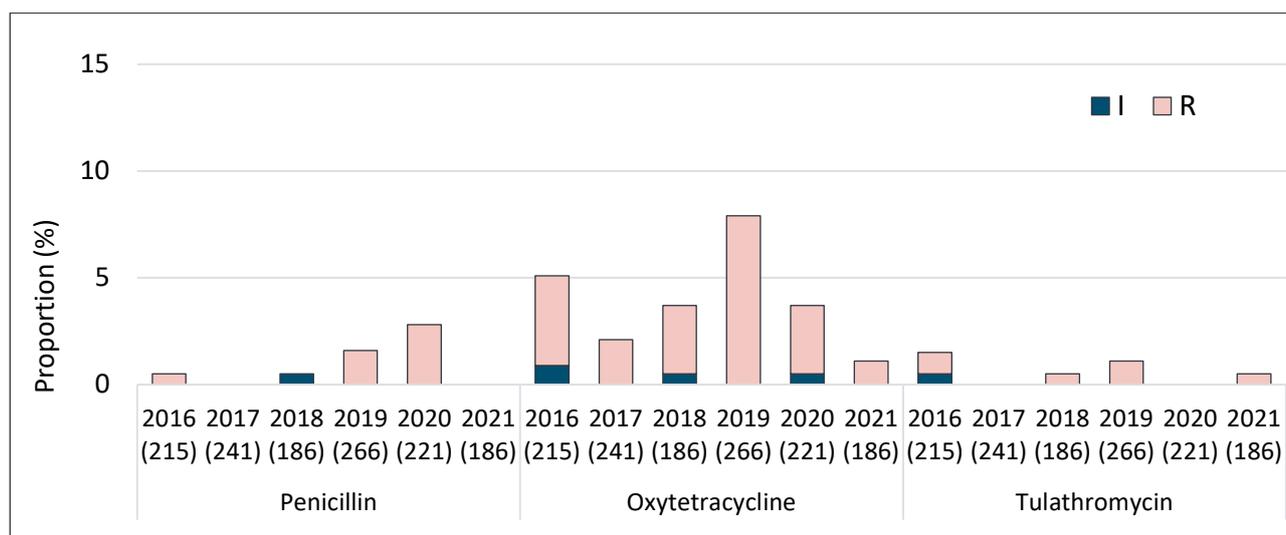
Figure 18. Proportion (%) of Pasteurella multocida from bovine respiratory disease not susceptible to penicillin, oxytetracycline and tulathromycin in 2016–2021. The number of isolates tested each year are in brackets.

In 2021, *Mannheimia haemolytica* isolates were obtained from 72 farms and isolates were fully susceptible on 78% of these farms. This is roughly the same as the previous year (76%). None of the isolates were resistant to more than one antibiotic. Only one penicillin resistant and two oxytetracycline resistant isolates (all from separate farms) were isolated in 2021. Altogether, isolates from 13 farms had intermediate susceptibility to penicillin while no isolates had intermediate susceptibility to oxytetracycline. It seems that the proportion of isolates with intermediate susceptibility to penicillin is increasing, while the total proportion of not susceptible isolates has remained stable in recent years (Figure 19). Further, one isolate had intermediate susceptibility to enrofloxacin. The MIC distributions of different antibiotics for *M. haemolytica* isolated in 2021 are shown in Table 14.

Table 14. *Distribution of MICs for Mannheimia haemolytica from bovine respiratory disease in 2021 (n=79).*

Substance	%R	95% C.I.	0.12	0.25	0.5	1	2	4	8	16	32	64	>64
Ceftiofur	0.0	0.0–4.6		100									
Enrofloxacin	0.0	0.0–4.6	98.7		1.3								
Florfenicol	0.0	0.0–4.6			20.3	79.7							
Oxytetracycline	2.5	0.7–8.8			50.6	45.6	1.3			2.5			
Penicillin	1.3	0.2–6.8	29.1	51.9	17.7	1.3							
Tulathromycin	0.0	0.0–4.6					29.1	70.9					

Bold vertical lines indicate clinical breakpoints for susceptibility (left vertical line) and resistance (right vertical line). Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration.
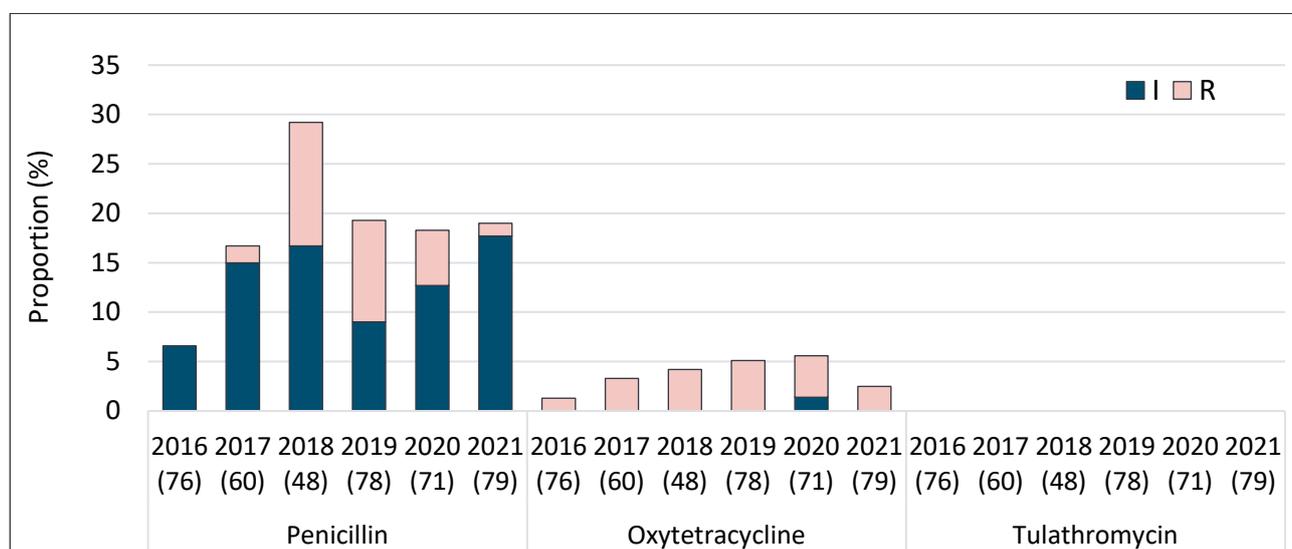
Figure 19. *Proportion (%) of M. haemolytica from bovine respiratory disease not susceptible to penicillin, oxytetracycline and tulathromycin in 2016–2021. The number of isolates tested each year are in brackets.*

5.5 *Escherichia coli* from colibacillosis in broilers

Colibacillosis infections in broilers and broiler parents are not treated with antibiotics in Finland. In spring 2021, there was an outbreak of colibacillosis that was mainly caused by one strain, ST23 O78. Rest of the year remained stable with colibacillosis and can be considered as normal situation. In 2021, altogether 141 *E. coli* strains were isolated from colibacillosis cases from 80 farms representing 117 different sample submissions. From the 141 isolates, 64 were typed as ST23 O78 and they were mostly susceptible to all the tested antibiotics. This has an impact for the levels of resistance obtained in 2021 from the isolated strains and therefore the resistance levels are somewhat lower than previously.

Based on epidemiological cut-off values, resistance to ampicillin, trimethoprim, sulfamethoxazole, and tetracycline was detected but only on low level (Table 15). Single isolates resistant against 3rd generation cephalosporins were found in 2016 and 2017 but not at all in 2018–2021. The occurrence of resistance

against different antibiotics has varied annually from zero to moderate levels (Figure 20). This is probably due to a small number of tested isolates as in 2020, or due to a big impact of one strain that is common as in 2021.
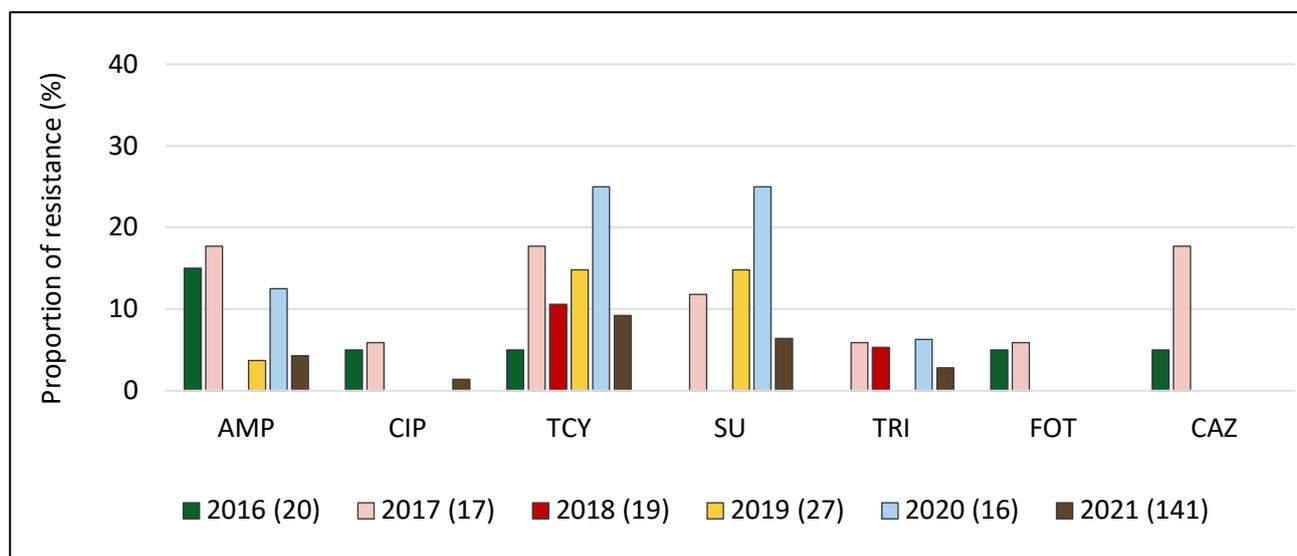
Figure 20. *Antibiotic resistance (%) in E. coli from colibacillosis in the years 2016–2021, epidemiological cut-off values. The number of isolates tested each year are in brackets.*

AMP, ampicillin; CIP, ciprofloxacin, TCY; tetracycline; SU, sulfamethoxazole; TRI, trimethoprim, FOT, cefotaxime; CAZ, ceftazidime.

5.6 *Staphylococcus aureus* from tenosynovitis in broilers

Staphylococcus aureus from broiler tenosynovitis cases were isolated from post-mortem samples submitted to Finnish Food Authority. All obtained *S. aureus* isolates were included. Nine isolates from seven broiler parent flocks were studied. All isolates were susceptible to the reported antibiotics (Table 16). None of the isolates were beta-lactamase producers or MRSA. Tenosynovitis is occasionally treated with antibiotics in broiler parent flocks. Production flocks have not been treated with antibiotics since 2010 (Animal Health ETT, 2022).

Table 16. *Distribution of MICs for Staphylococcus aureus from tenosynovitis in broilers in 2021 (n=9).*

Substance	%R	95%C.I.	Distribution (%) of MICs (mg/L)											
			0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64
Cefoxitin	0.0	0.0–29.9								100				
Penicillin[1]	0.0	0.0–29.9	88.9	11.1										
Tetracycline	0.0	0.0–29.9					100							
Trim/sulfa[2]	0.0	0.0–29.9				100								

Bold vertical lines indicate current (30.8.2022) epidemiological cut-off values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1]Resistance based on beta-lactamase production, [2]Concentration of trimethoprim given, tested with sulfamethoxazole in concentration ratio of 1:20

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Table 15. *Distribution of MICs for Escherichia coli from colibacillosis in 2021 (n=141).*

Substance	%R	95% C.I.	Distribution (%) of MICs (mg/L)																	
			0.015	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	1024	>1024
Ampicillin	4.3	2.0–9.0								17.0	74.5	4.3			4.3					
Cefotaxime	0.0	0.0–2.7			42.6	56.7	0.7													
Ceftazidime	0.0	0.0–2.7					94.3	5.7												
Ciprofloxacin	1.4	0.4–5.0	76.5	17.7	4.3	0.7	0.7													
Colistin	0.0	0.0–2.7							99.3	0.7										
Sulfamethoxazole[1]	6.4	3.4–11.7										75.2	18.4						0.7	5.7
Tetracycline	9.2	5.5–15.1							12.1	59.6	16.3	2.8	0.7		1.4	6.4	0.7			
Trimethoprim	2.8	1.1–7.1					27.0	55.3	12.8	2.1	0.7		1.4	0.7						

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration tested. [1]No EUCAST ECOFF is available, therefore, a cut-off value of >64 µg/mL is used (double vertical line) for resistance monitoring purposes.

6 Antibiotic resistance in animal pathogens from companion animals and horses

Antibiotic resistance figures from companion animal (dogs and cats) and horse pathogens were collected from the Clinical Microbiology Laboratory of the Faculty of Veterinary Medicine, University of Helsinki. In this context, antibiotic resistance corresponds to the proportion of resistant and intermediate isolates. The reporting period covers January 2014 – December 2020 and includes solely bacterial isolates derived from clinical infections. Screening specimens for multiresistant bacteria (MRSA, MRSP, ESBL) were omitted from the analysis. Approximately 35% of the specimens were from the Veterinary Teaching Hospital of the University of Helsinki and 65% from private clinics. If the number of tested bacterial isolates for the bacterial species in question was large enough for confident analysis, data are presented separately for dogs, cats, and horses. Otherwise, collated data are presented. Details of the susceptibility testing method are described in Appendix 3.

6.1 *Staphylococcus aureus* from companion animals and horses

Antibiotic resistance level in *S. aureus* of dogs, cats and horses was low (Figure 21), except for penicillin (not shown in figure). In 2021, 67% of the *S. aureus* isolates produced penicillinase, having been 67–69% in 2018–2020. The years 2014–2016 were omitted due to low number of isolates. The results for these years can be found in the previous FINRES-Vet reports.

Oxacillin resistance (indicating the presence of MRSA among S. aureus isolates) during the monitoring period remained generally at a low level, being around 7% in 2021. Of the seven MRSA isolates detected in clinical infections in 2021, two isolates were from dogs, two from cats and three from horses. The canine isolates were of spa type 034 (both from deep wounds of different dogs). The feline MRSA isolates were of spa 5354 (urine) and spa t026 (skin infection). The three MRSA infections in horses were related to the outbreak of MRSA CC398 (spa 011) in the Equine Teaching Hospital of the University of Helsinki.

6.1.1 Significance of resistance in *S. aureus*

S. aureus is a part of the normal microbiome of the skin and mucous membranes of cats and horses, as well as humans. As an opportunistic pathogen, it usually causes skin or wound infections in animals. Occasionally, there can be infections caused by *S. aureus* also in dogs. MRSA is considered to have zoonotic potential and may thus have an impact on public health.
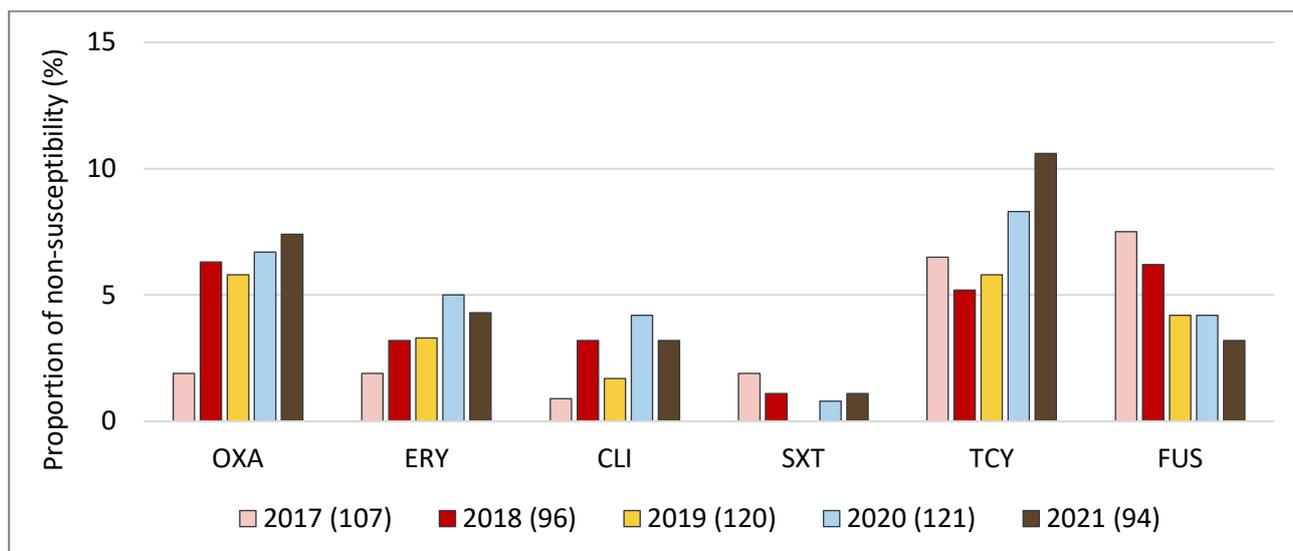
Figure 21. *Antibiotic non-susceptibility (%) in canine, feline, and equine S. aureus in 2017–2021. The number of isolates tested each year are in brackets. The years 2014–2016 were omitted due to low number of isolates.*

OXA, oxacillin; ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline; FUS, fusidic acid

6.2   *Staphylococcus pseudintermedius* from dogs

The proportion of MRSP isolates, indicated by oxacillin resistance, increased slightly from the year 2020 (5.7% in 2021, 4.5% in 2020). However, the proportion has declined drastically in during the last five years: in 2016, the proportion of MRSP was as high as nearly 14% of all *S. pseudintermedius* isolates (Figure 22). Penicillinase production remained high as out of the 665 tested *S. pseudintermedius* isolates in 2021, 85% produced penicillinase, which is a larger proportion than among *S. aureus* isolates (p<0.0001).

The overall non-susceptibility distribution of *S. pseudintermedius* isolates remained similar in 2021, when compared to the few previous years (Figures 22 and 23). Macrolide (erythromycin) and lincosamide (clindamycin) non-susceptibility slightly decreased from the year 2020, having been approximately 19% for both antibiotic classes. The highest proportion of non-susceptible isolates throughout the whole monitoring period was noted for tetracyclines. Tetracycline and doxycycline resistance levels were both at approximately 26%.

No resistance to amikacin was detected in clinical infection isolates of *S. pseudintermedius* in 2021.
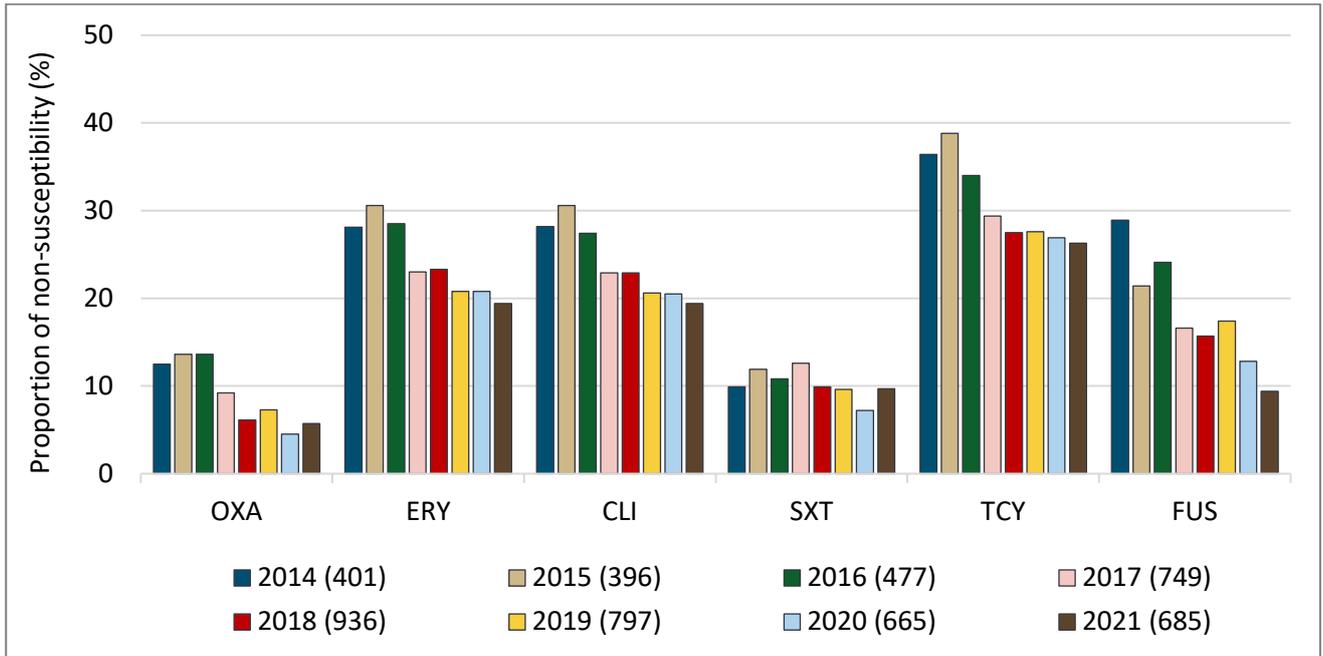
Figure 22. *Antibiotic non-susceptibility (%) for primary antimicrobial agents in canine S. pseudintermedius isolates in 2014–2021. The number of isolates tested each year are in brackets.*

OXA, oxacillin; ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline; FUS, fusidic acid
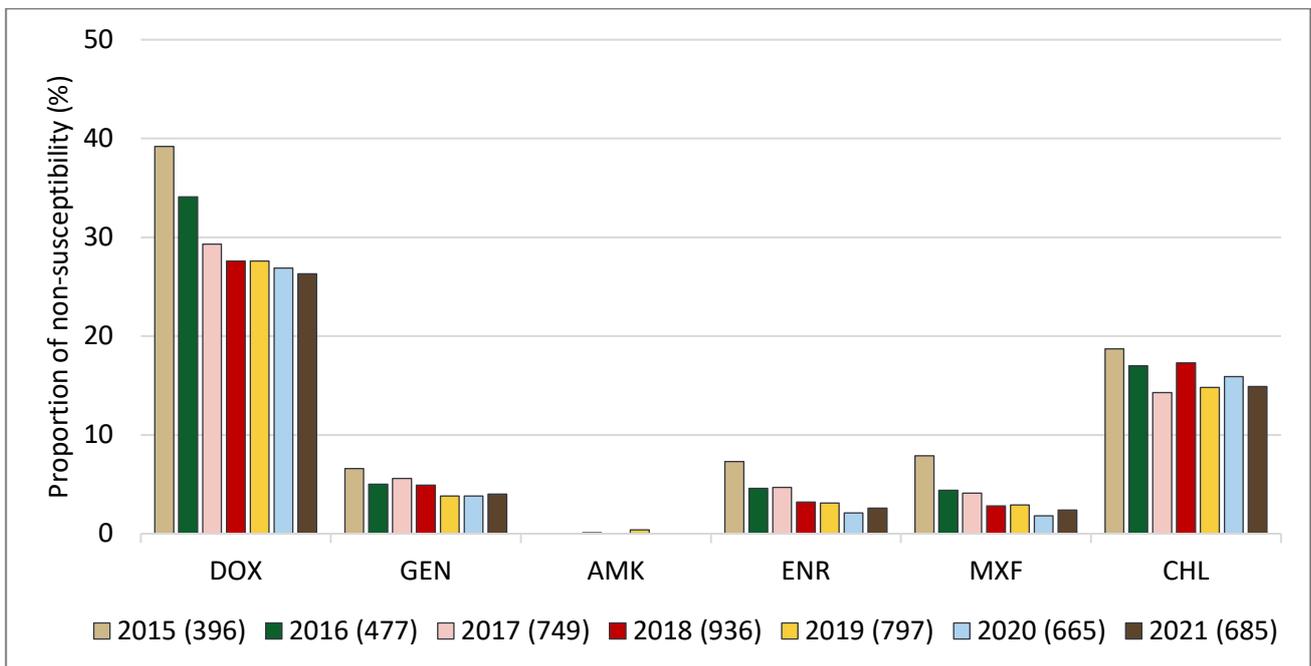
Figure 23. *Antibiotic non-susceptibility (%) for secondary antibiotics in canine S. pseudintermedius isolates in 2015–2021. The number of isolates tested each year are in brackets. The year 2014 was omitted due to small number of tested isolates.*

DOX, doxycycline; GEN, gentamicin; AMK, amikacin; ENR, enrofloxacin; MXF, moxifloxacin; CHL, chloramphenicol

6.2.1 Significance of resistance in *S. pseudintermedius*

S. pseudintermedius belongs to the normal microbiome of the skin and mucous membranes in dogs and rarely in cats. It is an opportunistic pathogen that most often causes skin or wound infections and occasionally urinary infections. Although the proportion of oxacillin resistance and thus the proportion of MRSP among *S. pseudintermedius* isolates has increased since the last report, the current overall resistance status remains fair. Many of the infections caused by *S. pseudintermedius* can be treated locally and thus the use of antibiotics can be avoided altogether.

As stated earlier, 85% of the isolates produced penicillinase, which is a major proportion. A penicillinase-producing isolate is resistant to many commonly used beta-lactam antibiotics, such as amoxicillin and penicillin. *S. pseudintermedius* is a moderately common urinary pathogen in dogs. Since a majority of *S. pseudintermedius* isolates produce penicillinase, knowing this might affect the empirical choice of antibiotic in treating for example sporadic cystitis in a dog, if a coccal species is suspected to have caused the infection.

6.3   *Escherichia coli* from dogs and cats

Resistance figures for canine and feline *E. coli* are presented in Figure 24 and 25, respectively. While ampicillin non-susceptibility decreased in canine *E. coli*, a slight increase in amoxicillin-clavulanic acid was observed. It may be that the year 2018 was a statistical anomaly as no other explanation for a sudden drop in non-susceptibility level of ampicillin was identified. In feline isolates, ampicillin resistance remained similar to previous years. Amoxicillin-clavulanic acid non-susceptibility was analogous for both cats and dogs. More specifically, in 2021 27% of all the canine *E. coli* isolates were classified as resistant to ampicillin, and 4% were resistant to amoxicillin-clavulanic acid, which could implicate that aminopenicillins still could be used in most cases of infection, if treated with an increased dosage. This could be applied at least to urinary bladder infections, as beta-lactams concentrate well in urine, and *E. coli* is the most common pathogen in canine and feline urinary bladder infections.

Enrofloxacin non-susceptibility in canine *E. coli* isolates remained on a low level, having been roughly 4% in 2021 (2% were resistant). Trimethoprim-sulfamethoxazole resistance in canine and feline *E. coli* fluctuated through the monitoring period, having been 11% in dogs and 3% in cats in 2021.

In 2021, 3.6% of canine *E. coli* were resistant to cefpodoxime, indicating reduced susceptibility to third generation cephalosporins (Figures 24 and 26). The proportion AmpC-producing isolates remained at around 3%, and for ESBL-producers the number remained well below 1% (0.4% in 2021 and 2020) (Figure 26). The proportion of isolates resistant to cefpodoxime in feline *E. coli* decreased from the year 2020 (2.7% in 2021, 4.8% in 2020).
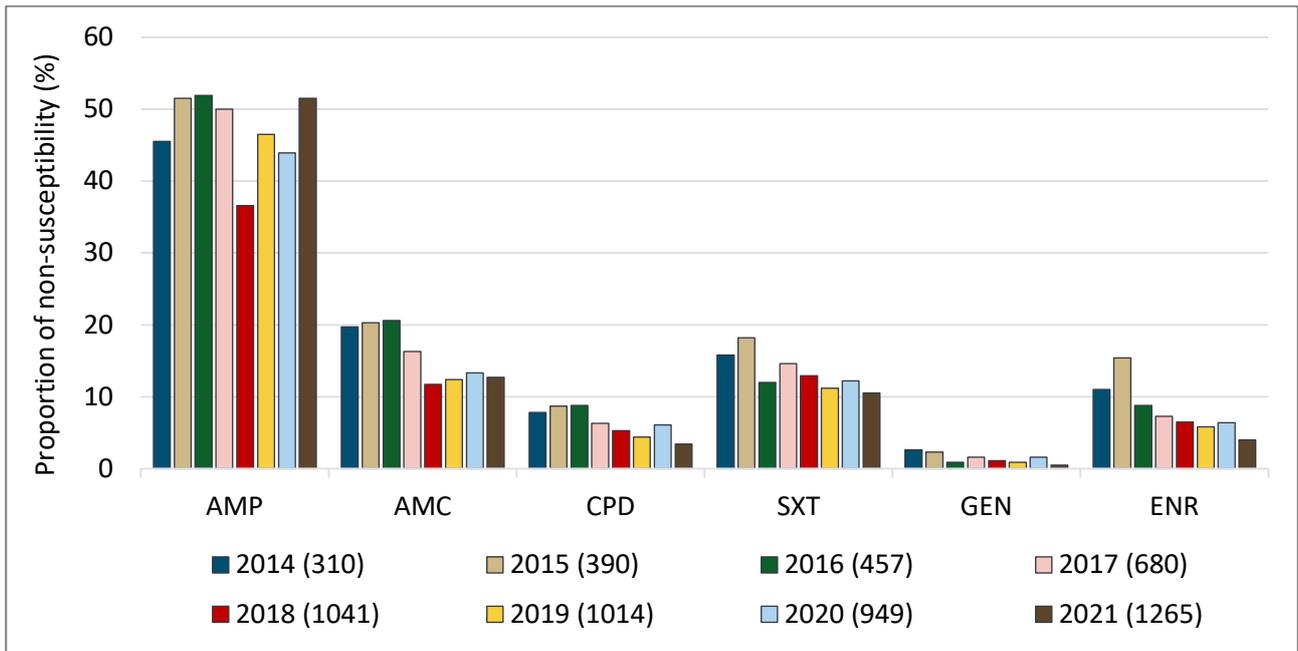
Figure 24. Antibiotic non-susceptibility (%) in canine E. coli in 2014–2021. The number of isolates tested each year are in brackets.

AMP, ampicillin; AMC, amoxicillin-clavulanic acid; CPD, cefpodoxime; SXT, trimethoprim-sulfamethoxazole; GEN, gentamicin; ENR, enrofloxacin
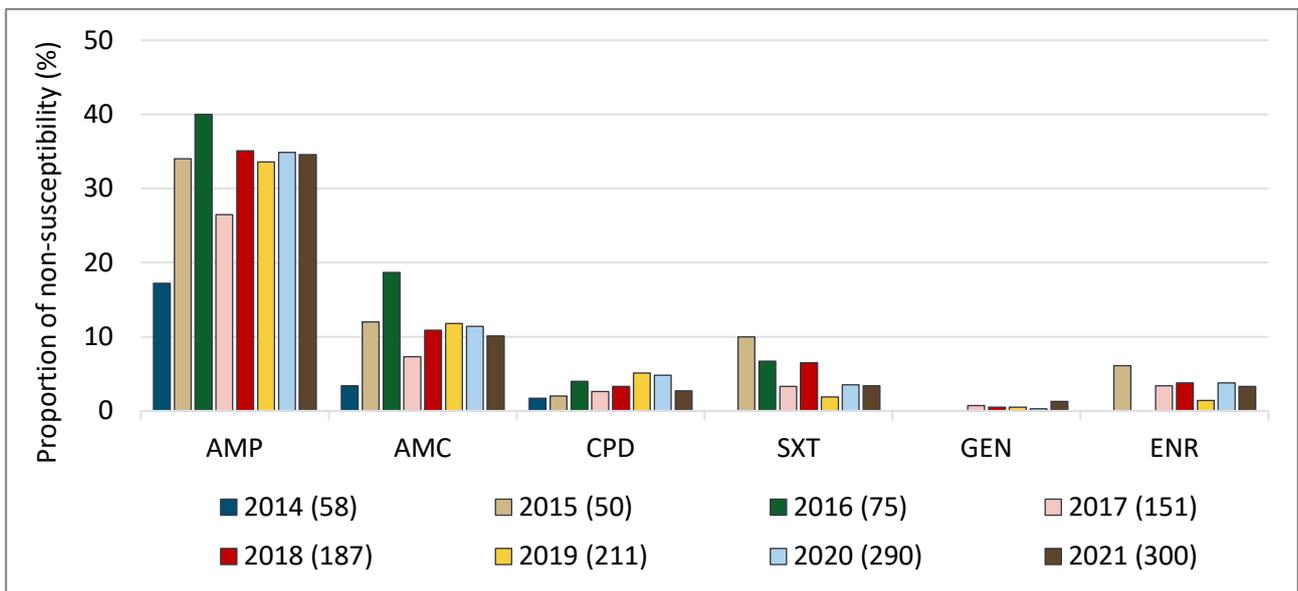
Figure 25. Antibiotic non-susceptibility (%) in feline E. coli in 2014–2021. The number of isolates tested each year are in brackets.

AMP, ampicillin; AMC, amoxicillin-clavulanic acid; CPD, cefpodoxime; SXT, trimethoprim-sulfamethoxazole; GEN, gentamicin; ENR, enrofloxacin
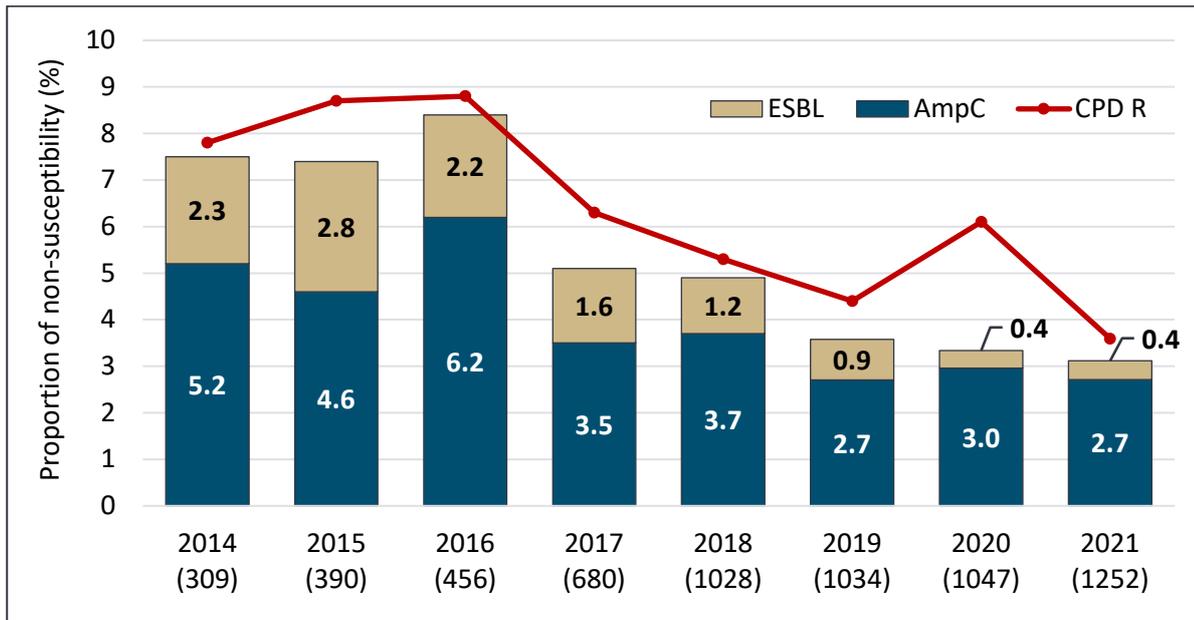
Figure 26. *The proportion of isolates with reduced susceptibility to cefpodoxime (CPD), and the proportion of ESBL and AmpC positive isolates in canine E. coli in 2014–2021. The number of isolates tested for CPD each year are in brackets. Only CPD resistant isolates were tested for phenotypic ESBL/AmpC production.*
CPD, cefpodoxime; AmpC and ESBL, extended-spectrum beta-lactamases

6.4   Streptococci from dogs and horses

In 2021, all tested canine *Streptococcus canis* isolates were susceptible to penicillin. However, there were two isolates resistant to trimethoprim-sulfamethoxazole (Figure 27). Resistance against this clinically important antimicrobial has not been seen since 2019. Macrolide (erythromycin) and tetracycline (tetracycline, clindamycin) non-susceptibility decreased slightly. It is worth noting that from the beginning of 2019 *S. canis* isolates from *otitis externa* specimens were not tested for systemic-only antimicrobials (e.g. penicillin, trimethoprim-sulfamethoxazole, erythromycin and clindamycin). Thus, the number of tested isolates for tetracycline has been greater ever since.
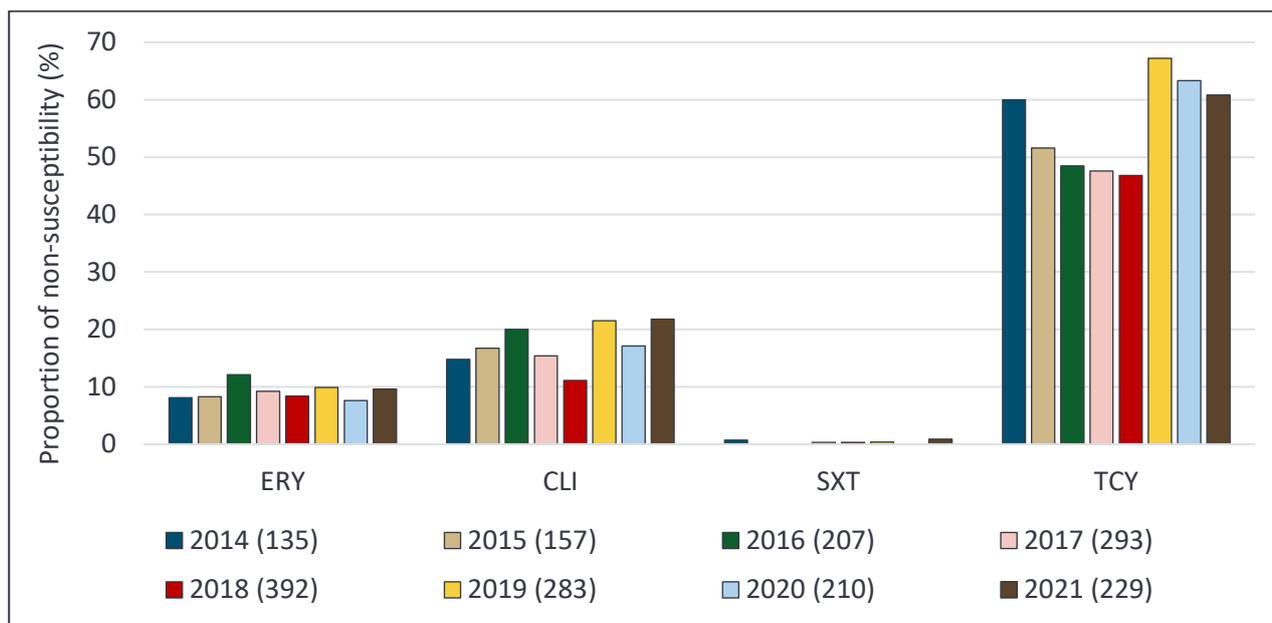
Figure 27. *Antibiotic non-susceptibility (%) in canine S. canis isolates in 2014–2021. The number of isolates tested each year are in brackets (in 2019, 351 isolates and in 2020, 258 isolates were tested for tetracycline susceptibility).*

ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline

In 2021, 54 *Streptococcus equi* ssp. *zooepidemicus* isolates were found in equine infection specimens. All isolates were susceptible to penicillin. It is noteworthy that almost 10% of the isolates were not susceptible to trimethoprim-sulfamethoxazole (four isolates classified as resistant, one as intermediate susceptibility (Figure 28). The development of resistance to this antibiotic substance has to be monitored carefully due to the importance of it in the treatment of many equine infections.
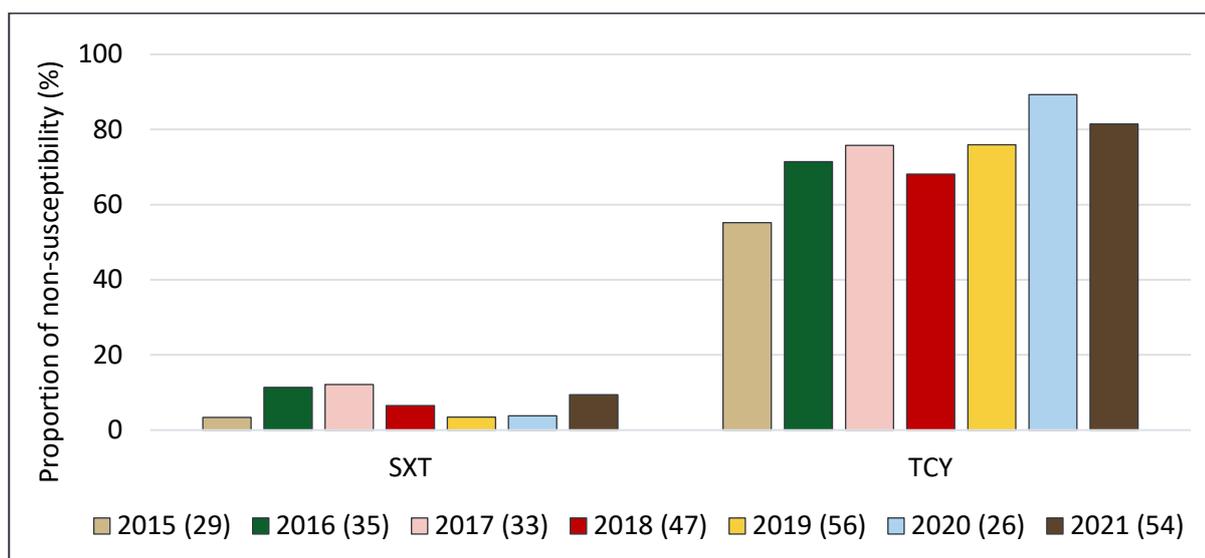
Figure 28. *Antibiotic non-susceptibility (%) in equine S. equi ssp. zooepidemicus isolates in 2015–2021. The number of isolates tested each year are in brackets. Year 2014 was omitted due to small number of tested isolates.*

SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline

6.5 *Pseudomonas aeruginosa* from dogs

In 2021, 65 canine clinical infection isolates of *P. aeruginosa* were tested. Overall, the isolates were quite susceptible to all tested antibiotics, as noted in previous years (Figure 29). None of the isolates expressed amikacin non-susceptibility in 2021, and the gentamicin non-susceptibility level was lower than in 2020. No resistance to colistin or tobramycin was detected. Most of the isolates (91%) were susceptible to ciprofloxacin. For enrofloxacin, 30% of the isolates were classified as resistant (84% non-susceptible).
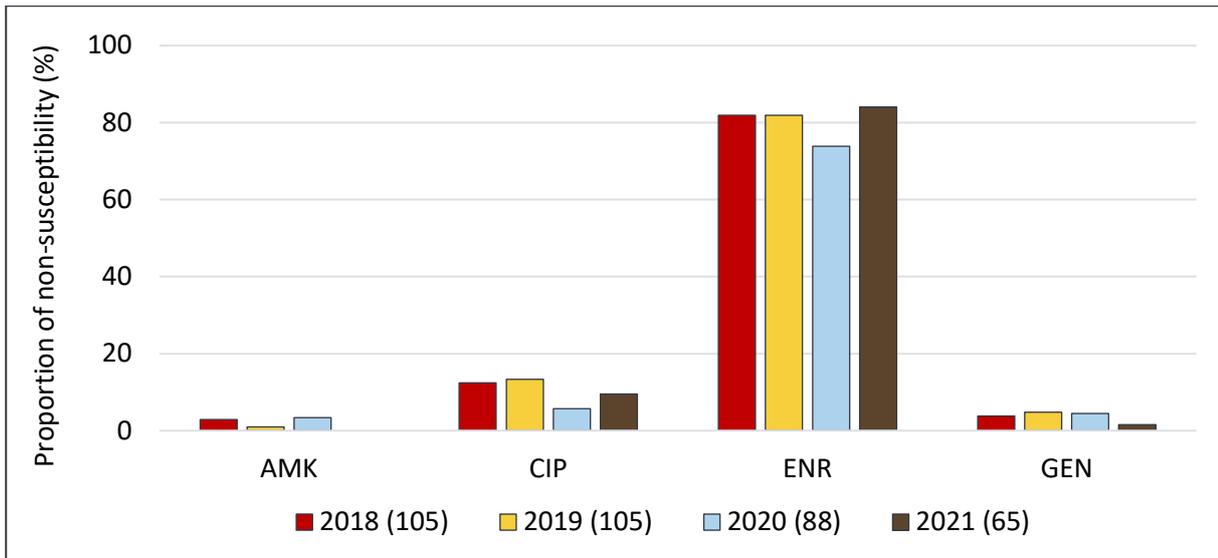
Figure 29. *Antibiotic non-susceptibility (%) in canine P. aeruginosa isolates in 2018–2021. The number of isolates tested each year are in brackets.*

AMK, amikacin; CIP, ciprofloxacin; ENR, enrofloxacin; GEN, gentamicin

7 Antibiotic resistance in indicator bacteria from food-producing animals

Resistance in commensal indicator *E. coli* is thought to show the most common resistance traits among the gram-negative bacteria present in the gut microbiota, and to reflect the selection pressure caused by the antibiotics used in the animal population in question. In this report, the results of the indicator *E. coli* from slaughtered, healthy pigs are presented. Details of the sampling and laboratory analysis are described in Appendix 3.

7.1 Indicator *E. coli* from pigs

In 2021, a total of 170 isolates from pigs were tested for antibiotic susceptibility. Resistance was overall low (Table 17) and the majority (78%) of the isolates was fully susceptible to the tested antibiotics (Figure 31). The resistance traits detected were against tetracycline (14%), trimethoprim (12%), sulfamethoxazole (12%) and ampicillin (8%) (Table 17). Altogether, 8% of the isolates were multidrug resistant. ESBL or AmpC isolates were not detected.

Resistance levels mostly increased between 2004 and 2015 and have since then been mostly decreasing (Figure 30). Resistance to tetracycline has been most commonly found. In 2021, the proportion of tetracycline-resistant isolates was similar than in 2019 and has overall decreased since 2013. In 2021, the proportion of isolates resistant to ampicillin reached its lowest point since 2013. Ciprofloxacin resistance has been at a low level throughout the monitoring period and no ciprofloxacin-resistant isolates were detected in 2021. The proportion of isolates resistant to trimethoprim increased from 2019 while the proportion of isolates resistant to sulfamethoxazole stayed at a similar level as in 2017 and 2019.
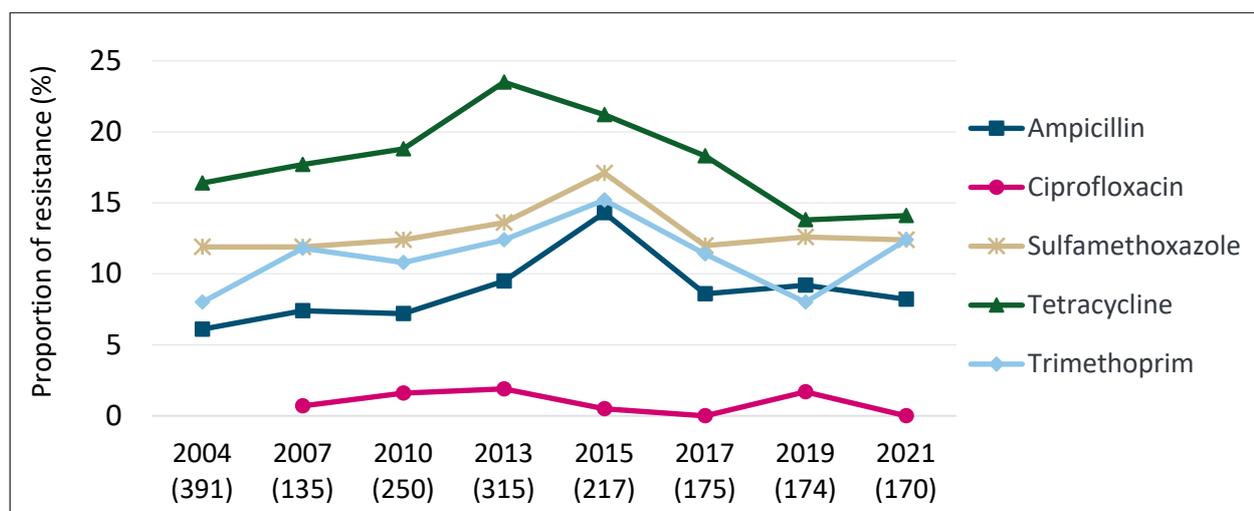
Figure 30. *Resistance in indicator E. coli from pigs to selected antibiotics in 2004–2021. The number of isolates tested each year are in brackets.*

Table 17. Distribution of MICs for indicator Escherichia coli in pigs in 2021 (n=170).

Substance	%R	95% C.I.	0.015	0.03	0.06	0.12	0.25	0.5	1	2	4	8	16	32	64	128	256	512	>512
													Distribution (%) of MICs (mg/L)					
Amicacin	0.0	0.0–2.2									98.8	1.2							
Ampicillin	8.2	5.0–13.3								30.0	56.5	5.3			8.2				
Azithromycin[1]	0.0	0.0–2.2								2.9	37.6	58.8	0.6						
Cefotaxime	0.0	0.0–2.2					100												
Ceftazidime	0.0	0.0–2.2					92.9	7.1											
Chloramphenicol	0.0	0.0–2.2										95.9	4.1						
Ciprofloxacin	0.0	0.0–2.2	94.1	5.3	0.6														
Colistin	0.0	0.0–2.2							98.8	1.2									
Gentamicin	0.0	0.0–2.2						86.5	12.9	0.6									
Meropenem	0.0	0.0–2.2		100															
Nalidixic acid	0.0	0.0–2.2									99.4	0.6							
Sulfamethoxazole[2]	12.4	8.2–18.1										55.9	29.4	2.4					12.4
Tetracycline	14.1	9.7–20.2								82.9	2.9				14.1				
Tigecycline	0.0	0.0–2.2					100												
Trimethoprim	12.4	8.2–18.1					39.4	34.1	11.2	2.9				12.4					

Bold vertical lines indicate current (30.8.2022) EUCAST epidemiological cut-off (ECOFF) values for resistance. Hatched fields denote range of dilutions tested for each substance. Values above the range denote MIC values greater than the highest concentration in the range. MICs equal to or lower than the lowest concentration tested are given as the lowest concentration. [1] A tentative EUCAST ECOFF. [2] No EUCAST ECOFF is available, therefore, a cut-off value of >64 µg/mL is used (dashed vertical line) for resistance monitoring purposes.
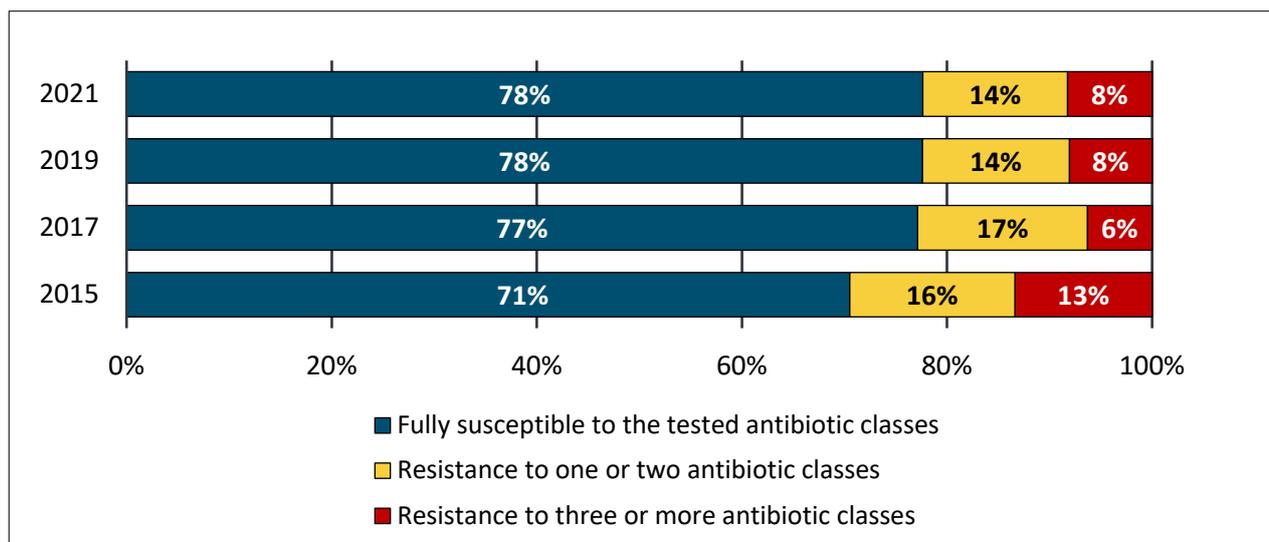
Figure 31. *Antibiotic susceptibility of indicator E. coli from pigs at slaughter in Finland between the years 2015 and 2021. The numbers of tested isolates each year are the same as in Figure 30. Antibiotic classes included in the analysis: aminoglycosides, beta-lactams, glycylcyclines, phenicols, polymyxins, quinolones, sulfonamides, tetracyclines and diaminopyrimidines (trimethoprim).*

Table 18. *Resistance profiles of multidrug resistant indicator E. coli from pigs in 2015, 2017, 2019 and 2021.*

Resistance profile	Nr of isolates in each year			
	2015	2017	2019	2021
AMP-TET-SU-TRI-CIP-NAL-CHL			1	
AMP-TET-SU-TRI-CHL-GEN	1			
AMP-TET-SU-TRI	12	5	3	5
TET-SU-TRI-NAL		1		
AMP-SU-TRI-CHL		1		
TET-SU-TRI-GEN	1			
TET-SU-TRI	9	7	4	4
AMP-SU-TRI	4	2	1	5
AMP-TET-SU	1	1	3	
AMP-TET-TRI	1	1		
TET-SU-CIP-NAL			1	
SU-TRI-CHL			1	
AMP-TET	6	3		2
AMP-SU	2	2	4	
TET-SU	1			
TET-CIP-NAL	1		1	
SU-TRI	3	1	2	6
TET-TRI		1	1	1
AMP-CAZ-FOT[1]			1	

Resistance profile	Nr of isolates in each year			
	2015	2017	2019	2021
AMP-TRI	1			
SU-CHL			1	
TET	13	13	10	12
AMP	3		3	2
SU	3	1	1	1
TRI	1	1	1	

Abbreviations: AMP, Ampicillin; CAZ, ceftazidime; CHL, chloramphenicol; CIP, ciprofloxacin; FOT, cefotaxime; GEN, gentamicin; NAL, nalidixic acid; SU, sulfamethoxazole; TET, tetracycline; TRI, trimethoprim. Multiresistant phenotypes are bolded [1] Phenotypically AmpC

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Appendix 1. Population statistics

The population of food-producing animals (as PCU) is presented in Table 19. The number of livestock and farms, and the production of meat and milk in Finland are presented in Tables 20–22 (Source: Luke, the Natural Resources Institute Finland).

Table 19. Population of food-producing animals as PCU (1000 tonnes) by species in 2011–2021.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cattle	227	224	224	226	229	228	222	220	213	207	205
Pigs	182	171	170	163	163	161	153	142	142	145	145
Poultry	62	65	67	68	70	73	76	82	83	85	86
Sheep and goats	11	11	11	11	13	13	13	13	12	12	11
Horses	30	30	30	30	30	30	30	30	30	30	30
Fish	11	13	14	13	15	14	15	14	15	15	14
TOTAL, PCU	522	514	516	512	520	520	508	500	496	494	491

Table 20. Number of livestock (in thousands) in Finland in 2011–2021.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cows	286	284	283	285	285	282	275	271	262	260	254
Suckler cows	57	58	57	58	59	59	60	60	60	62	64
Cattle > 1 year[1]	273	268	271	268	264	258	261	252	247	235	238
Calves < 1 year	299	303	300	303	307	310	297	299	288	290	289
TOTAL, Cattle	914	913	912	914	915	909	893	882	858	846	844
Boars and sows	146	136	128	123	NA	NA	NA	NA	NA	NA	NA
Pigs > 20 kg	797	779	815	760	NA	NA	NA	NA	NA	NA	NA
Piglets < 20 kg	392	375	365	362	NA	NA	NA	NA	NA	NA	NA
TOTAL, pigs	1 335	1 290	1 308	1 245	1 243	1 235	1 136	1 089	1 072	1 087	1 108
Laying hens	3 304	3 173	3 432	3 645	3 595	3 599	3 746	3 985	3 900	3 812	3 729
Chicks	745	743	858	714	662	748	509	608	647	566	796
Broilers	5 421	6 038	6 861	7 341	7 827	8 272	8 047	8 781	9 112	8 507	8 499
Turkeys	308	295	274	292	246	260	292	299	263	268	287
Other poultry[2]	457	512	555	584	597	566	543	468	438	424	570
TOTAL, poultry	10 236	10 761	11 981	12 577	12 927	13 445	13 136	14 140	14 360	13 577	13 881

[1] Heifers and bulls in total. [2] Including broiler parent hens, cockerels, ducks, geese, guinea fowls, ostriches, ranched ducks and pheasants. Number of cattle on 1.5. Number of pigs and poultry 1.4. Number of poultry in 2016 not totally comparable with the previous years. Source: OFS: Luke, Number of livestock.

Table 21. Number of farms in Finland in 2011–2021.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cattle farms	14 919	14 141	13 416	12 885	12 389	11 791	11 175	10 530	9 851	9 301	8787
Pig farms	1 917	1 747	1 637	1 486	1 337	1 240	1 102	1 027	963	918	864
Poultry farms	1 314	1 155	1 207	1 299	1 310	1 300	1 280	1 243	1 172	1 201	553

Source: OFS: Luke, Number of livestock.

Table 22. The production of meat and fish (million kg) in Finland in 2011–2021.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beef[1]	84	81	81	83	86	87	86	87	88	87	86
Pork[1]	202	193	195	186	192	190	182	169	171	176	176
Poultry[1]	102	107	111	113	117	125	129	135	139	145	147
Total	387	382	387	383	397	403	397	391	398	408	409
Fish[2]	11	13	14	13	15	14	15	14	15	15	15

[1] In slaughterhouses. The production of beef and pork corrected according to the latest statistics. [2] for human consumption, ungutted. Source: OFS: Luke, Meat production and Aquaculture.

Table 23. The production of milk in Finland in 2011–2021.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Milk production; per animal (litres)	7 859	7 876	7 977	8 201	8 323	8 406	8 534	8 650	8 810	9 038	9 042
Total milk production (million litres)	2 234	2 230	2 260	2 330	2 365	2 359	2 336	2 328	2 305	2 336	2 247

Source: OFS: Luke, Milk and milk products statistics.

Appendix 2. Sales of antibiotics for animals, kg active ingredient

Table 24. *Overall sales of veterinary antibiotics in Finland in 2011–2021, kg active ingredient.*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tetracyclines	1 838	1 759	2 389	2 576	2 250	2 010	2 268	2 218	2 677	1 830	1 780
Amphenicols	124	61	121	84	80	87	104	112	117	109	124
Penicillin G[1]	4 709	4 504	4 442	4 231	4 058	3 544	3 771	3 805	3 705	3 824	3 918
Aminopenicillins	1 284	1 342	1 314	1 374	1 498	1 438	1 160	1 020	1 011	934	1 012
Cloxacillin	112	97	82	91	65	63	45	39	33	39	48
1st gen. cephalosporins	1056	902	793	753	605	513	355	284	227	184	169
3rd gen. cephalosporins	9	15	8	8	7	3	1	0.5	0.2	0.2	0.2
Sulfonamides and trimethoprim	3 045	3 149	3 129	2 893	2 445	2 460	2 216	1 870	2 119	1 646	1 980
Macrolides	532	575	456	521	596	517	408	411	221	192	190
Lincosamides	164	179	155	189	165	120	297	184	197	61	56
Aminoglycosides	128	108	103	101	93	87	73	61	59	42	27
Fluoroquinolones	102	107	105	113	94	99	80	81	66	70	69
Pleuromutilins	73	66	43	44	30	23	14	10	3	2	0
Others										0	5
Total sales[1]	**13 174**	**12 864**	**13 140**	**12 979**	**11 987**	**10 964**	**10 790**	**10 095**	**10 435**	**8 932**	**9 378**

[1]Conversion factors for penicillins updated based on ESVAC 2021 protocol. Affects sales of penicillin G and total sales.

Table 25. *Sales of injectable veterinary antibiotics in Finland in 2011–2021, kg active ingredient.*

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tetracyclines	515	521	558	552	640	686	671	642	741	644	602
Amphenicols	12	13	26	17	6	13	26	15	23	24	25
Penicillin G[1]	4 557	4 279	4 270	3 981	3 781	3 230	3 538	3 564	3 479	3 565	3 692
Aminopenicillins	404	434	379	416	473	453	338	286	279	229	271
1st gen. cephalosporins	0	0	0	0	0	5	1	1	0	0	0
3rd gen. cephalosporins	9	15	8	8	7	3	1	0.5	0.2	0.2	0.2
Sulfonamides and trimethoprim	297	360	344	358	373	322	317	286	292	252	213
Macrolides	13	11	12	12	15	19	13	10	9	9	7
Lincosamides	30	27	24	26	26	25	19	18	19	24	21
Aminoglycosides	18	20	12	15	13	14	12	10	10	12	7
Fluoroquinolones	85	84	83	90	72	78	63	66	50	56	55
Total sales of injectables[1]	**5 938**	**5 763**	**5 718**	**5 475**	**5 406**	**4 849**	**4 999**	**4 899**	**4 902**	**4 815**	**4 893**

[1]Conversion factors for penicillins updated based on ESVAC 2021 protocol. Affects sales of penicillin G and total sales.

Table 26. Sales of orally administered veterinary antibiotics (premixes, oral solutions, oral powders, oral pastes, and tablets) in Finland in 2011–2021, kg active ingredient

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tetracyclines	1 323	1 237	1 830	2 024	1 610	1 324	1 597	1 575	1 936	1 186	1 178
Amphenicols	112	48	95	67	74	74	78	97	94	85	99
Penicillin G	17	110	47	122	147	190	100	105	94	118	92
Aminopenicillins	860	893	923	947	1 017	976	813	728	728	700	740
1st gen. cephalosporins	1 025	871	766	730	587	493	341	274	219	182	169
Sulfonamides and trimethoprim	2 747	2 789	2 784	2 535	2 072	2 138	1 899	1 584	1 828	1 394	1 767
Macrolides	519	565	444	510	581	498	395	402	212	183	182
Lincosamides	134	152	130	164	139	94	278	165	178	37	35
Aminoglycosides	79	76	76	70	62	54	41	32	29	8	14
Fluoroquinolones	17	23	22	22	22	22	16	15	15	14	14
Pleuromutilines	73	66	43	44	30	23	14	10	3	2	0
Imidazole derivatives	-	-	-	-	-	-	-	-	-	0	5
Total sales of orally adm. products	**6 906**	**6 829**	**7 160**	**7 236**	**6 342**	**5 885**	**5 571**	**4 986**	**5 338**	**3 909**	**4 281**

Table 27. Sales of intramammaries for veterinary use in Finland in 2011–2021, kg active ingredient

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Intramammaries for lactation phase											
Penicillin[1]	100	88	88	93	88	80	86	91	87	93	90
Aminopenicillins	14	11	8	8	7	7	6	5	3	4	1
Cephalexin	30	31	27	22	18	15	13	9	8	2	0
Cloxacillin	56	47	39	41	31	29	19	18	15	25	23
Aminoglycosides	12	1	0	0	0	0	0	0	0	0	0
Macrolides	1	0	0	0	0	0	0	0	0	0	0
Total lactation phase[1]	**213**	**178**	**162**	**164**	**144**	**131**	**123**	**123**	**113**	**124**	**114**
Intramammaries for dry cow treatment											
Penicillin	36	27	37	35	41	44	47	45	45	49	45
Aminopenicillins[2]	6	5	4	3	2	2	3	1	0	0	0
Cephalexin	1	0	0	0	0	0	0	0	0	0	0
Cloxacillin	55	49	43	50	35	34	26	21	18	14	26
Aminoglycosides	20	12	16	15	18	19	20	20	20	21	19
Total dry cow[1]	**117**	**93**	**100**	**104**	**96**	**100**	**97**	**87**	**83**	**85**	**90**

[1]Conversion factors for penicillins have been updated in accordance with ESVAC 2021 protocol. Affects sales of penicillin and total sales of intramammaries for lactation phase. [2]Sales of aminopenicillins in 2020 corrected.

Appendix 3. Materials and methods, resistance monitoring

Sampling strategy

Zoonotic bacteria

Salmonella isolates from food-producing animals were collected as required by the Finnish salmonella control programme. One isolate from each notified incident was included. Isolates from domestic food included also isolates originating from in-house control systems.

Campylobacter were isolated from broilers by the industry in association with the Finnish Campylobacter programme for broilers. Samples were taken from healthy animals at the slaughterhouses covering approximately 99% of all broilers slaughtered in Finland. Between 1st of June and 31st of October, every slaughtered broiler production batch was sampled, and between 1st of November and 31st of May, the frequency is set annually depending on production volume. From each epidemiological unit (slaughter batch), a caecal sample was taken from ten animals. All isolates (one isolate per slaughter batch) were included in the antibiotic susceptibility testing.

Campylobacter coli from pigs were isolated between February and December from healthy animals at slaughter from the three biggest slaughterhouses that accounted for >99% of all pigs slaughtered in Finland. The number of randomly taken samples from each slaughterhouse was proportional to the annual slaughter volume. From each epidemiological unit (slaughter batch), caecal sample was taken from one animal. If several samples from the same epidemiological unit was taken, only one sample was taken for further analysis. The samples were taken aseptically and transported refrigerated to the laboratory within two days. Samples were collected between Monday and Thursday. One campylobacter isolate from each epidemiological unit (if available) was selected for susceptibility testing.

Animal pathogens

Clinical isolates originated from diagnostic submissions or post-mortem examinations done in the laboratories of Finnish Food Authority. *Escherichia coli* was isolated from pigs with enteritis, the samples were taken from the contents of the gastrointestinal tract. All isolates examined were confirmed to be enterotoxigenic using PCR for toxin and fimbrial genes. *Staphylococcus aureus* from broiler tenosynovitis cases were isolated from post-mortem samples submitted to Finnish Food Authority. All obtained *S. aureus* isolates were included from the study period. *A. pleuropneumoniae* isolates originated from post-mortem investigations of lungs most likely from pigs with respiratory disease. Bovine respiratory pathogens were mostly from deep nasopharyngeal swabs from non-medicated calves suffering from acute respiratory disease. Also isolates from post-mortem investigations of cattle lungs were included. *E. coli* isolates from broilers were from post-mortem samples from parent or production pedigree, and isolated either from bone marrow or heart. *Brachyspira pilosicoli* isolates were from faecal samples of swine with diarrhoea. *Campylobacter jejuni* were isolated from fur animals with diarrhoea.

Antibiotic resistance figures from companion animal pathogens were collected from the clinical microbiology laboratory of the Faculty of Veterinary Medicine, University of Helsinki. All isolates included in this report originated from clinical specimens. The data were available for the period of 2014-2021.

MRSA in pork

Altogether, 206 samples of packed fresh and chilled (not frozen) meat were collected at retail between May and November 2021 to represent the pork on market in Finland. Samples were randomly selected and collected from retail shops in five different NUTS-3 areas, covering approximately 55% of the Finnish population. Sampling was evenly distributed throughout the study period and allocated according to meat batches. The meat samples were sliced or diced and wrapped in vacuum or in a controlled atmosphere. Collected samples represented fresh pork meat of domestic (n=199) and non-domestic (n=7) origin.

Samples were transported refrigerated to the laboratory within one day. The temperature of the meat was measured at the laboratory at arrival.

MRSA and ESBL/AmpC/carbapenemase-producing E. coli in fur animals

MRSA and ESBL/AmpC/carbapenemase-producing *E. coli* were screened from domestic, farmed fur animals between March 2020 and April 2021. A convenience sampling was performed from fur animals sent for pathological-anatomical diagnosis or for corona virus screening to the Finnish Food Authority laboratories.

Altogether, 106 pharyngeal/nasopharyngeal swab samples originating from 81 different holdings (57 holdings with minks, 13 holdings with blue foxes and 11 holdings with raccoon dogs) were screened for MRSA, and 106 rectal swab samples were screened for ESBL-, AmpC- and carbapenemase-producing *E. coli*. Each sample was a combination sample from one to five individual animals taken with one swab stick. Additionally, from each animal, one front paw was cut at the carpal joint and paws from one to five animals were treated as one sample and screened for MRSA. Samples were transported to the laboratory within 4 days and the analysis was started within 10 days from the sampling.

Indicator bacteria and ESBL/AmpC/carbapenemase-producing E. coli in food-producing animals

Indicator *E. coli* was isolated from pig caecal samples in 2021. From the same samples, the ESBL/AmpC and carbapenemase producing *E. coli* were screened. The samples from pigs (n=307) originated from healthy animals at slaughter between February and December. Sampling was evenly distributed throughout the monitoring period. The number of randomly taken samples from each slaughterhouse was proportional to the annual slaughter volume. Samples were collected at the three biggest slaughterhouses accounting for >99% of all pigs slaughtered in Finland. From each epidemiological unit (slaughter batch), a sample was taken from one animal. The samples were taken aseptically and transported refrigerated to the laboratory within two days. Samples were collected between Monday and Thursday. Indicator *E. coli* isolates were randomly selected for susceptibility testing from all isolates available at the laboratory. All presumptive ESBL/AmpC/carbapenemase producing *E. coli* were tested for antibiotic susceptibility.

ESBL/AmpC/carbapenemase-producing E. coli in imported poultry

ESBL/AmpC- and carbapenemase-producing *E. coli* were screened from the imported poultry flocks intended for broiler meat, turkey meat and chicken egg production chains. The sampling is instructed by the Animal Health ETT ry and includes the majority of imported parent and grandparent flocks. Also, the import of eggs intended for broiler production are screened regularly. The liners of ten transport boxes were collected from each imported flock if possible and sent to the laboratory as soon as possible. If the

import day was late Thursday, Friday or Saturday, the liners were moisturised with saline broth and kept at 4°C during the weekend.

ESBL/AmpC/carbapenemase-producing E. coli in meat

Randomly selected samples of packed fresh and chilled (not frozen) pork (n=313) and beef (n=308) were collected at retail between February and December in 2021. Sampling was evenly distributed throughout the study period and allocated according to meat batches. Samples were collected from retail shops in five different NUTS-3 areas, covering approximately 55% of the Finnish population. Because of the nature of the Finnish market (small size, only a few distributors), same batches of the product can be found throughout the country. Samples were collected from Monday to Thursday except for the biggest NUTS-3 area, where samples were also collected on Fridays. The meat samples were sliced or diced and wrapped in vacuum or in a controlled atmosphere. The majority of the samples (97%) were of domestic origin. The samples were transported refrigerated to the laboratory within one day and the temperature of the meat was measured at the laboratory at arrival. One isolate from each epidemiological unit (if available) was selected for susceptibility testing.

From border control posts, one meat sample including three packed, fresh, and chilled (not frozen) sub-samples from one consignment, was collected. The sample was transported refrigerated to the laboratory on the sampling day and the temperature of the meat was measured at the laboratory at arrival.

Isolation and identification of bacteria

Zoonotic bacteria

Salmonella spp. were isolated and identified according to a modification of the NMKL standard Nr 71 (1999), according to ISO standard 6579:2002 or ISO standard 6579:2002, Amendment 1/2007, at local food control or slaughterhouse laboratories. Serotyping of the isolates was performed at Finnish Food Authority, Veterinary Bacteriology and Pathology Unit.

C. jejuni and *C. coli* from broilers were isolated at slaughterhouse laboratories and confirmed at Finnish Food Authority, Microbiology Unit, according to ISO 10272-1:2017. *C. coli* from pigs were isolated according to ISO 10272-1:2017 with modifications mentioned in [Statens veterinärmedicinska anstalt (SVA) protocol for isolation, identification and storage of Campylobacter jejuni and/or C. coli for the EU monitoring of antimicrobial resistance (version 1, 2020)](). In short, caecal content from pigs was directly spread on mCCD (Oxoid) and Butzler (prepared in-house) agars using 10 µl loops. The plates were then incubated at 41.5 °C for 44+/- 4 hours (possibly up to 72 hours) and typical looking colonies were pure-cultured on blood agars and incubated at 41.5 °C or 37 C for 24-48 hours. Presumptive campylobacter colonies were then re-cultured on blood agars and incubated as in the first round of pure culturing.

Isolation and identification of *C. jejuni* from fur animals was performed by accredited conventional culture and biochemical/MALDI-TOF methods at Finnish Food Authority, Veterinary Bacteriology and Pathology Unit.

Animal pathogens

Isolation and identification of pathogens from food-producing animals was performed by accredited conventional culture and biochemical/MALDI-TOF methods at Finnish Food Authority, Veterinary Bacteriology and Pathology Unit.

Identification of pathogens from companion animals was performed by conventional biochemical methods (2014–2015) and since then by MALDI-TOF method in the clinical microbiology laboratory of the Faculty of Veterinary Medicine, University of Helsinki. Pathogens were from various types of specimens, such as superficial and deep pus specimens, urine, respiratory tract, and blood.

Screening of MRSA

MRSA was screened using selective enrichment broth and solid media. The method used was adapted from the EURL protocol. For fresh pork samples, 25 g of meat was diluted in 225 ml of Mueller Hinton broth with 6.5% NaCl. For MRSA screening of fur animals, each swab sample was suspended in 3 ml of Mueller Hinton broth with 6.5% NaCl. The amount of Mueller Hinton broth used for the pooled paw samples from minks varied from 40 to 280 ml depending on the weight of the paws. After an incubation at 37°C for 16-20 h, 10 μl of the enrichment broth was spread on MRSA Select2™ (Bio-Rad Laboratories) and Brilliance MRSA 2 (Oxoid) agar plates and incubated at 37°C for 18-28 h. Typical pink colonies were confirmed to Staphylococcus aureus using MALDI-TOF (Bruker, Germany). The presence of a *mecA* gene was confirmed with PCR. All MRSA isolates were *spa* typed.

Indicator E. coli

Caecal content was directly spread on Brilliance™ *E. coli*/coliform Selective Agar (Oxoid) and incubated overnight at 37°C. Typical, purple colonies were subsequently spread on blood agar plates and after an overnight incubation at 37°C, stored at -80°C until susceptibility testing.

Screening of ESBL-, AmpC- and carbapenemase-producing E. coli

Pig caecal samples (n=307) taken at slaughterhouses, fresh pork (n=313) and beef (n=308) samples taken at retail, and fresh beef (three sub-samples from one consignment) taken at border control post were screened as part of the EU-wide monitoring based on Commission Implementing Decision (EU) 2020/1729 according to the latest EURL protocols. Briefly, 1 g of intestinal content or 25 g of fresh meat was suspended in 10 ml or 225 ml of buffered peptone water (BPW) (Merck, Germany), respectively, and incubated overnight at 37°C. Subsequently, 10 μl of the suspension was spread on MacConkey agar plates (Becton, Dickinson & Company, France) containing 1 mg/l cefotaxime (Sigma-Aldrich, Germany) for the detection of ESBL/AmpC producers, and on CARBA and OXA-48 plates (Biomerieux) for the detection of carbapenemase producers. MacConkey plates were incubated overnight at 44°C, and CARBA and OXA-48 plates overnight at 37°C. Presumptive *E. coli* colonies from the selective plates were confirmed with MALDI-TOF (Maldi Biotyper®, Bruker Daltonics, Germany). The screening of imported poultry flocks was performed using the same methodology by analysing the liners from each imported flock as two combination samples (liners from 5 transport boxes suspended in 3 liters of BPW). The screening of rectal swab samples from fur animals was performed using the same methodology by suspending each swab in 3 ml of BPW.

Susceptibility testing

Verbal descriptions of the resistance levels are those used by EFSA (EFSA, 2010).

Rare	< 0.1%
Very low	0.1% to 1.0%
Low	>1% to 10%
Moderate	>10% to 20%
High	>20% to 50%
Very high	>50% to 70%
Extremely high	>70%

Bacteria from food-producing animals

The susceptibility testing of bacteria from food-producing animals was performed with broth microdilution method according to the Clinical and Laboratory Standards Institute (CLSI) standard VET01 5th ed (CLSI, 2018) using Sensititre[TM] (TREK Diagnostic Systems Ltd, United Kingdom) microtiter plates except for *Brachyspira* spp. for which MICRONAUT-S Brachyspira MIC (MERLIN A Bruker Company, Germany) were used. The confirmation of presumptive ESBL/AmpC-producing bacteria was done by the AmpC & ESBL ID Set (D68C, Mast Diagnostics, UK) (pathogenic *E. coli* from food-producing animals) or by the microdilution method using Sensititre[TM] EUVSEC2 plates (salmonella, indicator *E. coli and* isolates from the ESBL/AmpC screening). Beta-lactamase activity in *S. aureus* was tested with Cefinase[TM] disks (Becton Dickinson, NJ, USA).

Susceptibility testing was performed at the Microbiology Unit and for *Brachyspira* spp. at Veterinary Bacteriology and Pathology Unit. The current (30.8.2022) epidemiological cut-off (ECOFF) values were used to separate the wild-type population (referred as susceptible) from non-wild-type isolates (referred as resistant) (Table 28). When available, clinical breakpoints of the CLSI VET01S 5th ed document (CLSI, 2020) were used to evaluate clinical resistance in animal pathogens. For *Brachyspira* spp., no standardised breakpoints exist, and laboratory-specific breakpoints were used to evaluate clinical resistance.

Table 28. Cut-off values (mg/L) for resistance used in this report. Values represent EUCAST epidemiological cut-offs (ECOFFs) (30.8.2022). If EUCAST ECOFF was missing or different cut-off value was used it is stated in the footnote.

Substance	Salmonella enterica	Escherichia coli	Campylobacter coli	Campylobacter jejuni	Staphylococcus aureus
Amikacin	>4[1]	>8			
Ampicillin	>4	>8			
Azithromycin	>16	>16[1]			
Cefotaxime	>0.5[1]	>0.25			
Cefoxitin					>4
Ceftazidime	>2	>0.5			
Chloramphenicol	>16	>16	>16	>16	
Ciprofloxacin	>0.06	>0.06	>0.5	>0.5	

Substance	*Salmonella enterica*	*Escherichia coli*	*Campylobacter coli*	*Campylobacter jejuni*	*Staphylococcus aureus*
Colistin	[2]	>2			
Enrofloxacin		>0.125			
Erythromycin			>8	>4	
Florfenicol		>16			
Gentamicin	>2	>2	>2	>2	
Meropenem	>0.06[1]	>0.06			
Nalidixic acid	>8	>8	>16	>16	
Streptomycin		>16	>4	>4	
Sulfamethoxazole	>256[2]	>64[2]			
Tetracycline	>8	>8	>2	>1	>1
Trimethoprim	>2[1]	>2			
Trimethoprim/ sulfamethoxazole[3]		>1[4]			>0.25[1]

[1] tentative EUCAST ECOFF, [2] EUCAST ECOFF not available, [3] concentration of trimethoprim given, concentration ratio with sulfamethoxazole 1:20, [4] differs from ECOFF

Bacteria from companion animals

Susceptibility testing of bacteria isolated from companion animals was performed in in the clinical microbiology laboratory of the Faculty of Veterinary Medicine with a disk diffusion technique with an available CLSI VET01 (5th ed) standard (CLSI, 2018). For all data, clinical breakpoints of the standard CLSI VET01S 5th ed (CLSI, 2020) was used to calculate non-susceptibility percentages. Resistance percentages include resistant and intermediate isolates. If veterinary breakpoints were not available, the breakpoints available in CLSI M100 30th ed (CLSI, 2020b) were used. An exception was the fusidic acid non-susceptibility breakpoint, which was ≤ 23 (FiRe-standard, version 6). Beta-lactamase activity was tested with Cefinase[TM] disks (Becton Dickinson, NJ, USA). *S. aureus* with oxacillin or cefoxitin MIC values >2 or >4, respectively, were tested for the presence of the *mecA* gene with polymerase chain reaction (PCR) using primers described in Murakami *et al*. (1991).

Quality assurance system

The Veterinary Bacteriology and Pathology Unit of Finnish Food Authority participates in external quality assurance programmes for veterinary pathogens and in proficiency tests on isolation, identification and serotyping of Salmonella, and the Microbiology Unit participates in proficiency tests for antibiotic susceptibility testing.

For susceptibility tests the following bacteria were included as quality controls on at least a weekly basis: *E. coli* ATCC 25922, *S. aureus* ATCC 29213, *C. jejuni* ATCC 33560, *Actinobacillus pleuropneumoniae* ATCC 27090 and *Histophilus somni* ATCC 700025. For *Brachyspira* susceptibility test, *Brachyspira hyodysenteriae* ATCC 31212 was used as a quality control strain.

The Veterinary Bacteriology and Pathology Unit is accredited for isolation, identification and serotyping of salmonella, and the Microbiology Unit and the Bacteriology laboratory in Seinäjoki using Sensititre[TM]

susceptibility panels in the susceptibility testing according to SFS-EN ISO/IEC 17025, by the Finnish Centre for Metrology and Accreditation.

The clinical microbiology laboratory of the Faculty of Veterinary Medicine laboratory has internal quality control scheme with ATCC control strains; the quality control tests are performed on a weekly basis. In addition, the laboratory participates in several external quality control schemes (including identification and susceptibility testing of bacteria) organised by Labquality.

Appendix 4. Salmonella serovars isolated from food-producing animals in 2021

Table 29. *Salmonella enterica serovars isolated from the main food-producing animal species in Finland in 2021.*

Serotype	Nr of isolates	Cattle	Pigs	Poultry (Gallus gallus)	Turkeys
S. Typhimurium		8		3	
monophasic *S.* Typhimurium			3		
S. Enteritidis		2	1	2	
S. Altona		9			
S. Uganda			5		
S. Derby			4		
S. Cholerasuis			3		
S. Kentucky		3			
S. Konstanz		2			
S. Abony		1			
S. Infantis		1			
S. Overschie		1			
S. Braenderup				1	
S. Newport				1	
Sum	**50**	**27**	**16**	**7**	**0**

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