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FINRES-Vet 2019

Finnish Veterinary Antimicrobial Resistance Monitoring and Consumption of Antimicrobial Agents

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FINRES-Vet 2019

Finnish Veterinary Antimicrobial Resistance Monitoring and Consumption of Antimicrobial Agents

fimea
Finnish Medicines Agency

UNIVERSITY OF HELSINKI
FACULTY OF VETERINARY MEDICINE

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Abstract

Sales of veterinary antimicrobials in food-producing animal species in Finland remained low although it increased slightly in 2019. Majority, almost two thirds, of all antimicrobial products are given to individual animals, and products intended for group treatment accounted for just over a third. Injectable penicillin is still the most commonly used antimicrobial. The next most common agents are orally administered tetracyclines and orally administered sulfonamide-trimethoprim combination, both of which saw a clear increase in sales last year. Sales of reserve antimicrobials (HPCIA, WHO list) for the treatment of animals remained very low also in 2019.

The antimicrobial 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, there is a need to further emphasise the preventive measures and prudent use of antimicrobials. It is important to follow the Finnish recommendations for the use of antimicrobials in animals.

Among salmonella and campylobacter from Finnish food-producing animals, resistance levels were mainly low. For the first time in Finland, multidrug resistant monophasic *Salmonella* Typhimurium was isolated from a few cattle and pig farms in 2019. From 2014 onwards, the occurrence of fluoroquinolone and tetracycline resistant campylobacter from broilers have varied. No significant changes have been observed in the occurrence of resistant indicator *E. coli* from pigs except for tetracycline resistance which has decreased since 2013. The resistance situation among pathogenic bacteria isolated from food-producing animals was similar as in previous year. Resistant isolates are still detected most commonly among enterotoxigenic *E. coli* from pigs.

The proportion of resistant bacterial isolates from companion animals and horses decreased for nearly all antimicrobials. However, resistance against some antimicrobials increased for certain bacterial species.

The prevalence of ESBL/AmpC-producing bacteria in slaughtered pigs as well as in pork and beef was low or non-existent.

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Tiivistelmä

Eläinten mikrobilääkkeiden myynti Suomessa on vähäistä, vaikka vuonna se 2019 lisääntyikin hieman. Suurin osa, lähes kaksi kolmasosaa mikrobilääkkeistä annetaan eläinyksilöille ja ryhmälääkkeiden osuus oli reilu kolmannes. Injektiopenisilliini on edelleen käytetyin mikrobilääke. Seuraavina tulevat suun kautta annettavat tetrasykliinit sekä sulfonamidi-trimetopriimi-yhdistelmä, joiden molempien myynti lisääntyi viime vuonna selvästi. Ihmisen reserviantibioottien (HPCIA, WHO:n lista) myynti eläinten lääkintään pysyi edelleen erittäin vähäisenä.

Eläimistä ja elintarvikkeista eristettyjen bakteerien mikrobilääkeresistenssitilanne Suomessa on edelleen suhteellisen hyvä. Joillakin bakteereilla resistenssiä kuitenkin esiintyy kohtalaisesti tai yleisesti, joten eläinten mikrobilääkkeiden käyttötarpeen vähentämiseen ja hallittuun mikrobilääkkeiden käyttöön tulee edelleen kiinnittää huomiota. Eläimille annettuja mikrobilääkkeiden käyttösuosituksia on syytä noudattaa.

Kotimaisista tuotantoeläimistä eristetyillä salmonelloilla ja broilereista eristetyillä kampylobakteereilla resistenssiä todettiin pääasiassa vähän. Vuonna 2019 muutamilta suomalaisilta nauta- ja sikatiloilta todettiin ensimmäisen kerran moniresistentti monofaasinen *Salmonella* Typhimurium. Vuodesta 2014 alkaen broilereista eristetyillä kampylobakteereilla on todettu vaihtelevasti resistenssiä fluorokinoloneille ja tetrasykliinille. Sioista eristetyillä *E. coli* -indikaattoribakteereilla resistenssissä ei ole tapahtunut suuria muutoksia, mutta tetrasykliiniresistenssi on ollut laskusuunnassa vuodesta 2013. Tuotantoeläimille tautia-aiheuttavien patogeenien resistenssitilanteessa ei todettu merkittäviä muutoksia edelliseen vuoteen nähden. Eniten resistenssiä todettiin edelleen sikojen enterotoksisilla *E. coli* -kannoilla.

Seura- ja harrastuseläimistä eristettyjen bakteerien joukossa resistenssi väheni seurantajakson aikana lähes kaikkien mikrobilääkkeiden suhteen, mutta yksittäisten lääkeaineiden osalta nähtiin kuitenkin resistenssin lisääntymistä.

ESBL/AmpC-bakteereita esiintyi suomalaisissa teurassioissa sekä vähittäismyynnissä olevassa sian- ja naudanlihassa vähän tai ei ollenkaan.

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Försäljningen av antimikrobiella läkemedel för djur i Finland är låg även om den ökade något år 2019. Största delen, nästan två tredjedelar av de antimikrobiella läkemedlen, ges till djurindivider och drygt en tredjedel används som gruppläkemedel. Penicillin i injektionsform är fortfarande det mest använda antimikrobiella läkemedlet. Följande i ordningen är orala tetracykliner och kombinationen sulfonamid-trimetoprim. Försäljningen av båda ökade betydligt ifjol. Försäljningen av reservantibiotika (HPCIA, WHO:s lista) för behandling av djur var fortsatt 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 antimikrobiella medel för djur och för att kontrollera användningen av antimikrobiella medel. Det är viktigt att följa rekommendationerna för användning av antimikrobiella medel för djur.

Hos salmonellabakterier som isolerats från finska livsmedelsproducerande djur och kampylobakterier som isolerats från broilrar konstaterades endast en liten resistens. År 2019 konstaterades den multiresistenta monofasiska *Salmonella* Typhimurium för första gången på några finländska nöt- och svingårdar. Sedan 2014 har en varierande resistens mot fluorokinoloner och tetracykliner konstaterades hos kampylobakterier som isolerats från broilrar. Det har inte skett några större förändringar i resistensen hos *E. coli* -indikatorbakterier isolerade från svin, men tetracyklinresistensen har minskat sedan 2013. Bland patogener isolerade från livsmedelsproducerande djur konstaterades inga större förändringar i resistensen jämfört med året innan. Resistensen var fortfarande vanligast hos enterotoxiska *E. coli* -stammar från svin.

Under kontrollperioden minskade resistensen hos bakteriestammar som isolerats från sällskapsdjur mot så gott som alla antimikrobiella medel. För enstaka läkemedel ökade dock andelen resistenta stammar.

ESBL/AmpC-bakterier förekom i liten mån eller inte alls hos finska slaktsvin och i svinkött och nötkött som såldes i detaljhandeln.

CONTENTS

Introduction

FINRES-Vet 2019 reports statistics on sales of veterinary antimicrobials and antimicrobial resistance in bacteria isolated from animals. The FINRES-Vet programme is coordinated by the Finnish Food Authority (Ruokavirasto). Other collaborators are the Finnish Medicines Agency (Fimea) and the University of Helsinki.

Antimicrobial resistance in bacteria from animals has been monitored in Finland since the 1980's and the sales of veterinary antimicrobials since 1995. Initially resistance was screened in salmonella isolates from food-producing animals. Regular FINRES-Vet programme started in 2002 and it has been expanded gradually to include e.g. more animal pathogens and the screening of multiresistant bacteria from animals and food. Currently, resistance is monitored in zoonotic and indicator bacteria from production animals along with resistance of certain animal pathogens from production and companion animals. Resistance monitoring is based on the Commission Implementing Decision 2013/652/EU and as decided at the national level.

Monitoring resistance in zoonotic bacteria is important as resistance can transfer between bacteria, animals and humans, creating a risk also to human health. Similarly, resistance in animal pathogens needs monitoring in order to recognise emerging resistance traits, and to indicate effectiveness of antimicrobial 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 given population reflects the selection pressure caused by the use of antimicrobials. 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 antimicrobial agents used in veterinary medicine,
- to monitor antimicrobial resistance in bacteria from major food-producing animals, food and pets,
- 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.

The previous FINRES-Vet reports show a favourable overall resistance situation in bacteria isolated from animals and food of animal origin in Finland. This is probably due to the long history of strict antimicrobial policy, and active promotion of health and welfare of food-producing animal. National prudent use guidelines recommend choosing narrow spectrum antimicrobials and individual treatment whenever possible (Evira 2016). Altogether, overall sales of veterinary antimicrobials in Finland are low, penicillin is

the most used antimicrobial and majority of antimicrobials are given to individual animals. Even though the general resistance situation remains favourable, increase in resistance in some zoonotic bacteria and certain animal pathogens has been observed in recent years. This indicates that preventive measures need further improvement and the prudent use guidelines should be strengthened.

This ninth FINRES-Vet report covers years from 2010 to 2019. Data from previous years has been included to enable follow-up of trends. Resistance results presented comprise indicator bacteria (non-pathogenic *E. coli* from pigs), zoonotic bacteria (salmonella from food-producing animals and campylobacter from poultry), and several animal pathogens from the main food-producing animal species (pigs, cattle, poultry), fur animals, companion animals (dogs, cats) and horses. In addition, the results of the specific monitoring of extended-spectrum beta-lactamase producing *E. coli* from pigs, bovines and their meat is included.

The Finnish Food Authority coordinates the FINRES-Vet programme and monitors antimicrobial resistance in bacteria from food-producing animals. The Finnish Medicines Agency monitors sales of veterinary antimicrobials, 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 antimicrobial susceptibility data from companion animals and horses.

1 Use of therapeutic antimicrobials and feed additives for animals in Finland

1.1 Changes in animal population

Changes in the number of food-producing animals from 2018 to 2019 were relatively small. The decreasing trend in the number of pigs stopped, but number of cattle continued slow decrease. 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 is used to calculate animal population, which is described using Population Correction Unit (PCU). Since 2010, the PCU has decreased from 520 to 496 (thousand tons). PCU of pigs has decreased the most. At the same time, PCU of poultry has increased steadily.

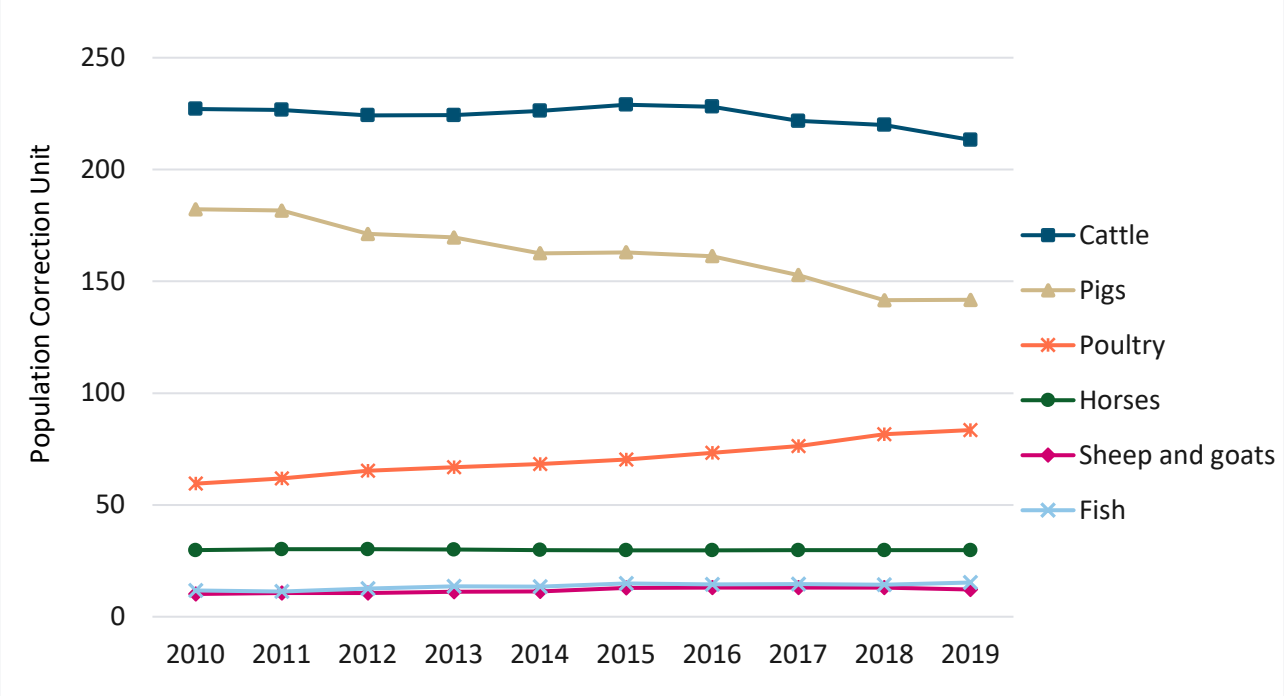

Figure 1. *Changes in food-producing animal population in Finland in 2010–2019, PCU. Detailed data on the PCU of food-producing animals in a tabulated form is presented in Appendix 1.*

Regarding the number of companion animals, Statistics Finland estimated that the number of dogs and cats in 2012 was 630 000 and 592 000, respectively. Newest information from 2016 estimated that the number of dogs had increased slightly to 700 000 while the number of cats remained stable.

1.2 Therapeutic antimicrobials

1.2.1 Background and methodology

Finnish Medicines Agency Fimea monitors the sales of veterinary antimicrobials based on statistics obtained from pharmaceutical wholesalers. Sales data reported as kg active ingredient is available since 1995. This report includes data for 2010–2019. For a review of data for 1995–2009, see the FINRES-Vet reports covering the corresponding years.

In 2010, data collection method was harmonised with the protocol of European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project (EMA, 2009). Data covers also veterinary antimicrobials sold with special licence (exemption from marketing authorisation, i.e. veterinary antimicrobial products obtained from another Member State and permitted to be marketed for specific animal species). In 2019, their proportion was approximately 5% of the total sales.

Sales data reports as kg active ingredient for overall sales and sales by different administration routes and pharmaceutical forms (injectables, orally administered antimicrobials, intramammaries and tablets). For intramammaries also sales of tubes per cow are presented.

To compare changes in annual sales of antimicrobials, 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 and slaughtered animals in a given 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), presents in this report for the EU-indicators of veterinary antimicrobial consumption i.e. overall sales, sales of fluoroquinolones and 3rd generation cephalosporins (ECDC, EFSA and EMA, 2017). Note that PCU adjusted data does not include tablets, as they are almost exclusively used in companion animals. Only estimates of the number of dogs and cats in Finland is 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 antimicrobials have decreased by 22% in 2010's (Figure 2). In 2019, sales increased by 2% and were 10 585 kg. Increased sales were noted especially in tetracyclines and in combination of sulfonamides and trimethoprim.

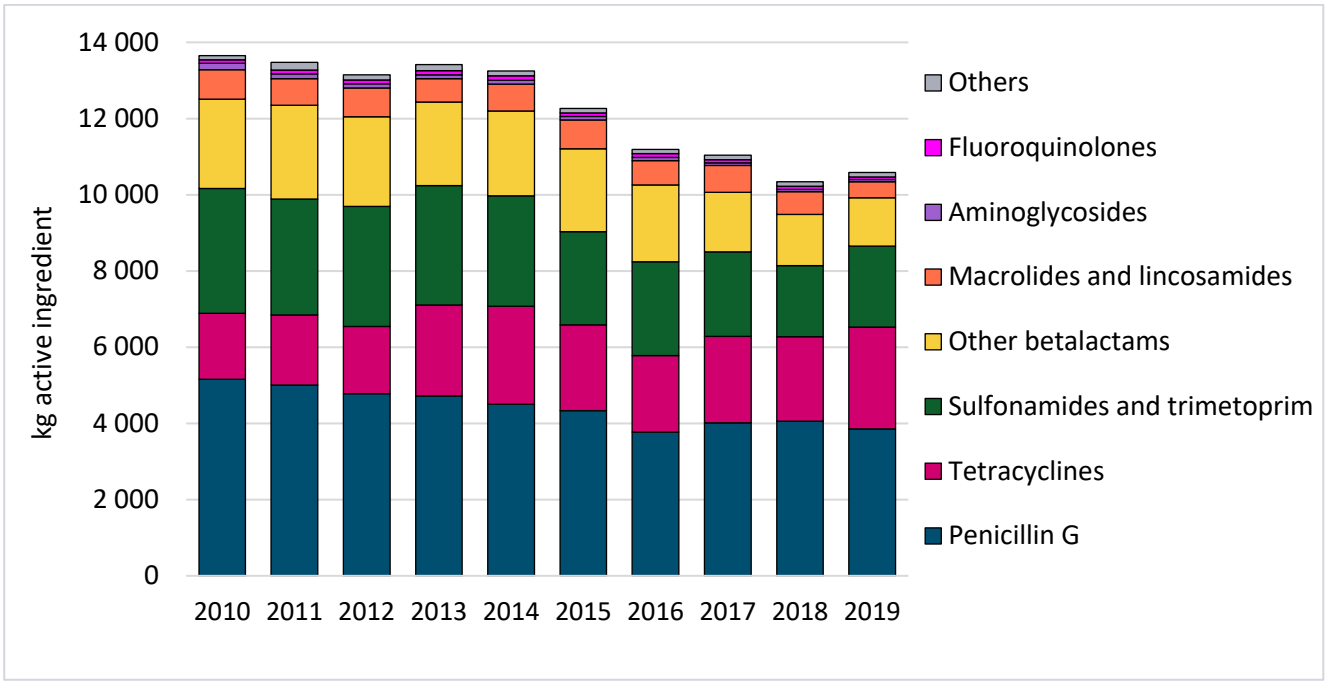

***Figure 2**. Overall sales (kg active ingredient) by class. Other betalactams = aminopenicillins, cephalosporins and cloxacillin. Others = pleuromutilines and amphenicol. Detailed data in a tabulated form is presented in Appendix 2.*

Almost two thirds of all antimicrobial products sold in 2019 were for treatment of individual animals (injectables, tablets, oral pastes and intramammaries) and the remaining third were products applicable for group treatment (premixes, oral powders and oral solutions) (Figure 3).

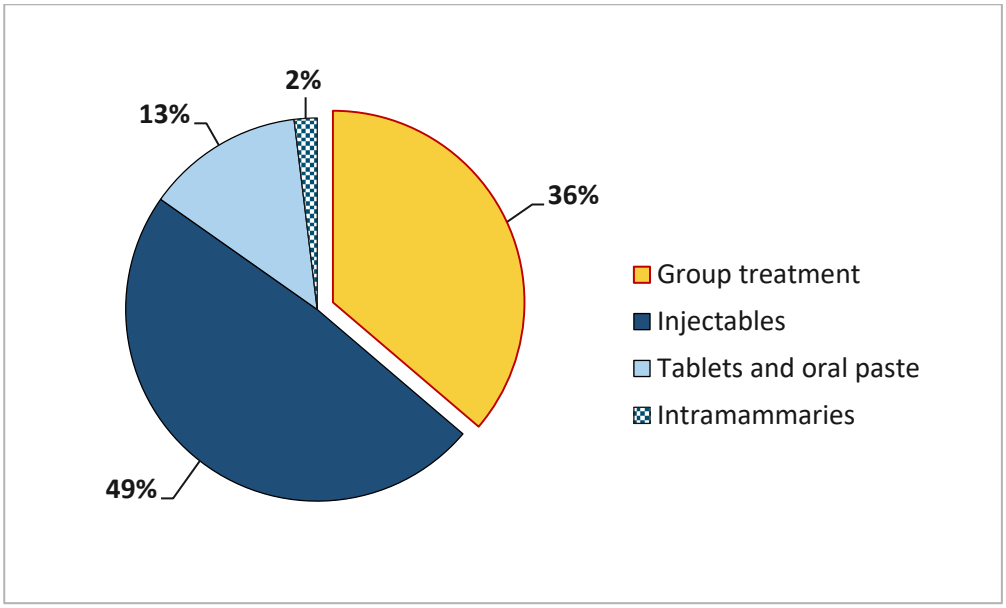

***Figure 3**. Sales of veterinary antimicrobials by form in 2019. Group treatment= premixes, oral solutions and oral powders.*

The most sold antimicrobials were penicillin G (36%), tetracyclines (25%) and the combination of sulfonamides and trimethoprim (20%) (Figures 2). The proportion of reserve antimicrobials (HPCIA, highest priority critically important antimicrobials, WHO list 6th revision 2019) remained low to extreme low: macrolides 2%, fluoroquinolones 0.6% and 3rd generation cephalosporins 0.002%.

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

Almost half of antimicrobials sold were products administered as injections to animals (Figure 3). By far the most sold injectable was benzylpenicillin (72% of injectables; figure 4A). A decreasing trend in sales of benzylpenicillin continued, and likely relates to the decreasing number of pigs and cows (Figure 1). The drop in sales of benzylpenicillin observed in 2015–2016 was due to large-scale shortage of these products in Finland (Happonen *et al*. 2017).

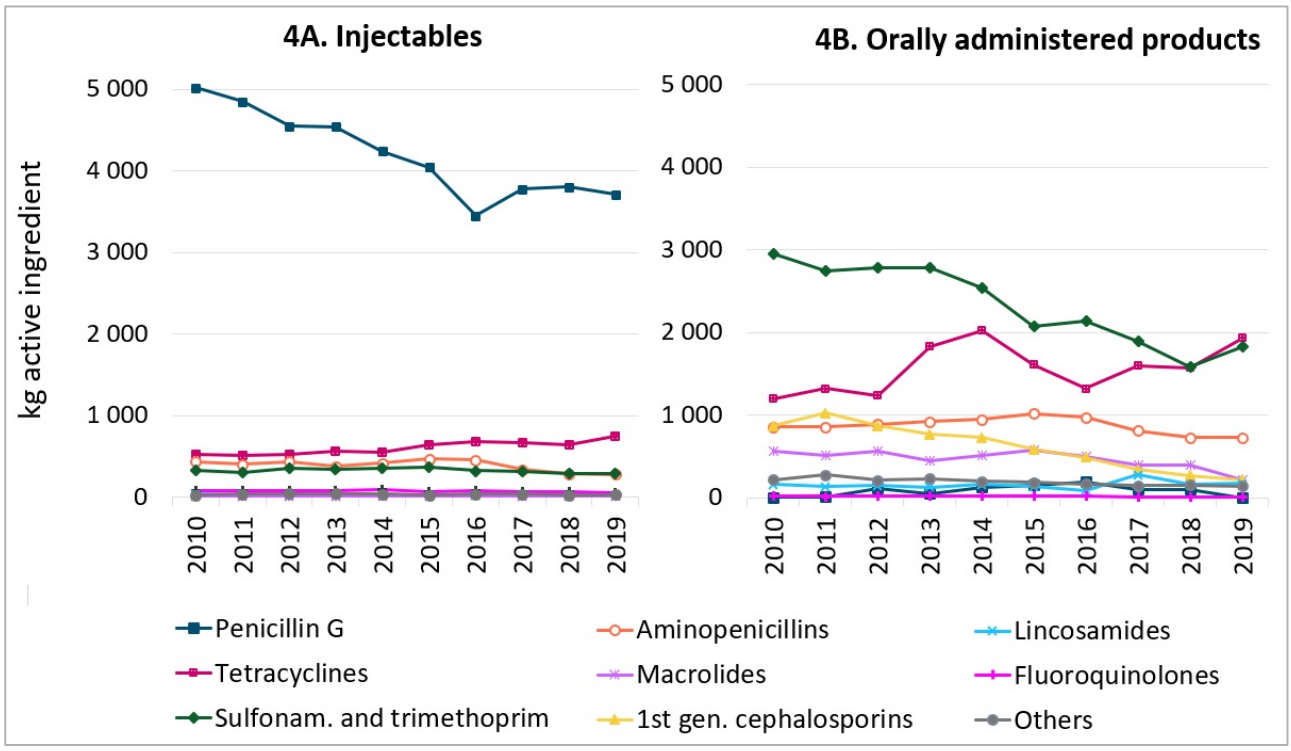

***Figure 4A and 4B**. Trends in sales of injectable veterinary antimicrobials (4A) and sales of orally administered veterinary antimicrobials (4B). Other injectables = amphenicols, aminoglycosides and cephalosporins, Other oral products = amphenicols, aminoglycosides and pleuromutilins. Detailed data in a tabulated form is presented in Appendix 2.*

After five years of reduction, sales of orally administered products turned to increase in 2019 (Figure 4B, Table 25 in appendix 2). Sales increased particularly in orally administered tetracyclines (+23% in 2019). Sales of orally administered sulfonamide-trimethoprim combination almost halved from 2010 to 2018 but turned to increase in 2019 (+15%). Although species-specific sales data is not available, it seems that the 2019 increase in sales of these two classes can largely be explained by increased sales to veterinarians treating fur animals.

Sales of 1st generation cephalosporins continued to decrease but to less extent than during the preceding five-year period (Table 25 in Appendix 2). Decrease in sales of aminopenicillin tablets observed from 2016 turned to increase in 2019 (+4%) (Figure 5). Both 1st generation cephalosporins and aminopenicillins are mainly sold as tablets for companion animals. During this decade more prudent use guidance has been directed to veterinarians treating companion animals and total sales of tablets for companion animals have more than halved since 2011 (-51%).

Statistics on the number of companion animals in Finland are not available, but it has been estimated that the number of dogs and cats has somewhat increased during this decade (section 1.1. Statistics Finland, 2016). Antimicrobials authorised for humans are also prescribed for companion animals, but current method of data collection does not capture this data. Nevertheless, the amount is anticipated to be modest, as legislation requires veterinarians to prescribe veterinary medicinal products if they are available.

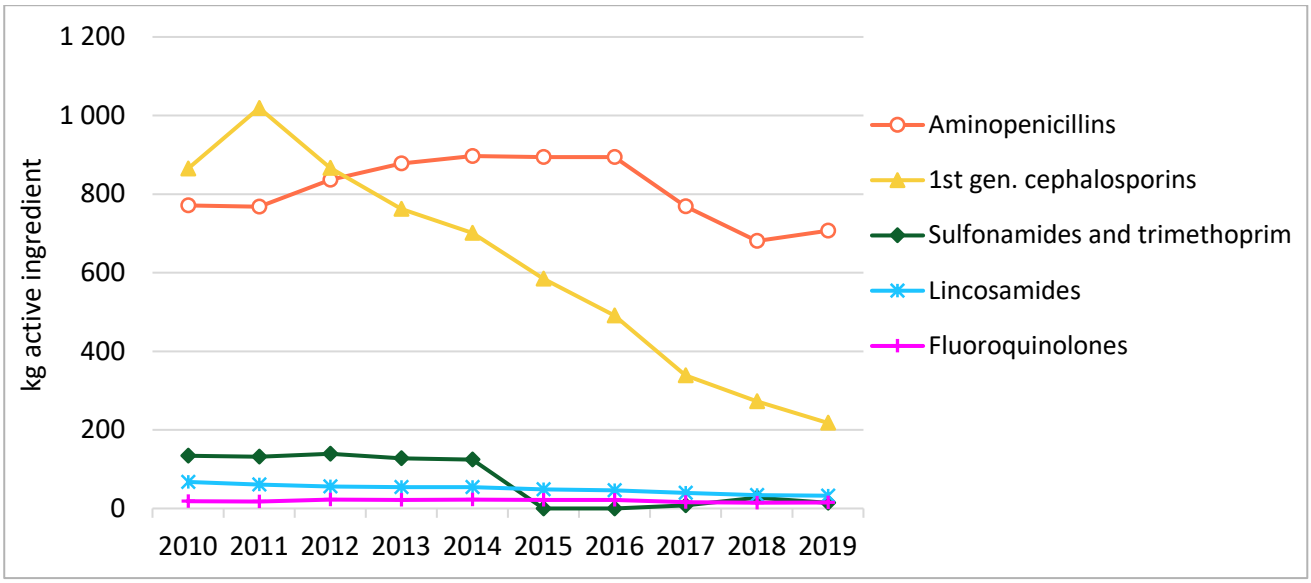

Figure 5. *Sales of antimicrobials tablets to companion animals (kg active ingredient) by class. Note that sulfonamide and trimethoprim combination tablets were withdrawn from the market in 2015.*

Number of intramammary products sold per cow during lactation period decreased through the decade and was approximately one tube per cow in 2019. This is rather close to the frequency of dry cow treatment per cow, which has been quite stable for a longer period (Figure 6).

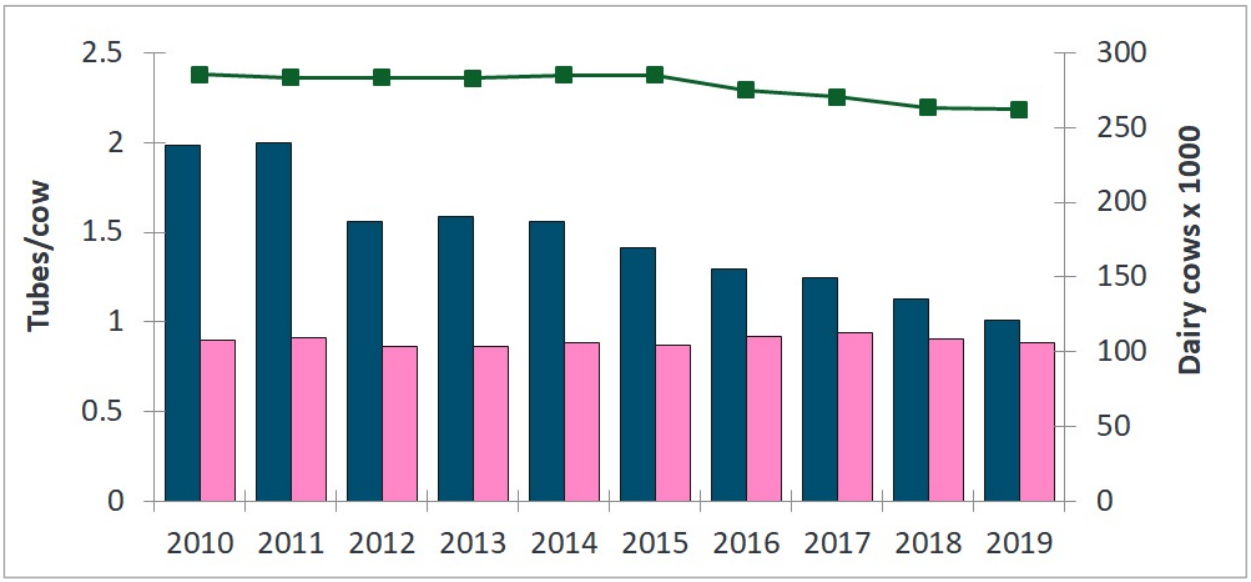

Figure 6. *Antimicrobials for intramammary use per cow during lactation period (blue column) and for dry cow period (pink column) and the number of dairy cows (green curve).*

1.2.4 EU-indicators of antimicrobial 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 antimicrobials and occurrence of AMR in both humans and food-producing animals. For food-producing animals, the indicators for antimicrobial consumption are overall sales of veterinary antimicrobials, sales of 3rd and 4th generation cephalosporins, sales of quinolones (specifying the proportion of fluoroquinolones) and sales of polymyxins, measured in mg/PCU (ECDC, EFSA ja EMA 2017). Of these, overall sales of veterinary antimicrobials, sales of 3rd generation cephalosporins and sales of fluoroquinolones are applicable in Finland.

Overall sales of veterinary antimicrobials in Finland are low. A decreasing trend in population corrected sales has continued almost through the decade (-16% from 2010 corresponding to 3.7 mg/PCU), though small fluctuations are seen. In 2019, a slight increase (+4% corresponding to 0.7 mg/PCU) was noted, but the overall sales remained modest. Detailed reasons for the changes in overall sales are generally not known, as current data sources allow very limited species-specific follow up. Probable contributors to the favourable low-sales situation are the legislative restrictions applied since 1949 (antimicrobials are prescription only and veterinarians are prohibited to profit from sales of antimicrobials) and early awakening to threat of antimicrobial resistance. Promotion of health and welfare of food-producing animals have been central principles in animal husbandry in Finland for several decades. Many important infectious animal diseases have been eradicated from Finland years ago. Considering prudent use guidance, Finland was amongst forerunners in providing advice to veterinarians already in 1996. The guidance was last updated in 2016 (Evira publications 2016).

Sales of 3rd generation cephalosporins continued to decrease in 2019 (-52% from 2018). Similarly, sales of fluoroquinolones decreased markedly (-46% from 2018 to 2019). Probable contributing factors are the

control measures targeted towards the veterinarians using the highest amounts of these antimicrobial classes. Another likely factor is the prerequisite to test bacterial susceptibility before using HPCIA introduced to national law in 2014.

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

Sales (mg/PCU)	2010	2011	2012	2013	2014	2015	2016	2017	2018[1]	2019
Overall	23	22	22	22	22	20	19	19	19	19
Fluoroquinolones	0.15	0.16	0.16	0.16	0.18	0.14	0.15	0.12	0.13	0.07
3rd generation cephalosporins	0.009	0.017	0.029	0.016	0.016	0.014	0.006	0.001	0.001	0.0005

[1] Overall sales in 2018 corrected compared to FINRES-Vet 2018

1.3 Coccidiostats and antimicrobial feed additives

Finnish Food Authority (formerly Finnish Food Safety Authority Evira) monitors the annual consumption of feed additives by collecting data from feed manufacturers. In Finland, the coccidiostats monensin natrium and narasin are used as prophylactic anti-parasitic agents mainly in broiler and turkey production. In 2019, small amount of another coccidiostat, 0.04 kg diclazuril (active substance/year), was also used. The overall use of coccidiostats slightly decreased from 2016 to 2018 but increased again in 2019 (Table 2).

Table 2. *The use of coccidiostats, antimicrobial feed additives and other substances in feed in Finland 2010–2019 (kg active substance/year).*

Substance	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coccidiostats										
Decoquinate	0	0	0	0	0	0	0.1	0	0	0
Diclazuril	0	0	0	0	0	0	0	0.8	0.5	0.04
Lasalocid sodium	1.4	0	0	0	0	0	0	0	1 336	0
Madmuramycin ammonium	0	0	0	0	0	0	0	0	0	0
Monensin natrium	6 801	5 837	7 300	4 614	6 677	12 640	15 373	14 693	5 097	13 979
Narasin	5 859	7 658	6 567	9 626	9 022	5 478	5 026	4 918	13 152	6 535
Salinomycin	1 701[1]	495[2]	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
Flavomycin	0	0	0	0	0	0	0	0	0	0
Carbadox	0	0	0	0	0	0	0	0	0	0

Substance	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	**13 832**	**13 991**	**13 867**	**14 240**	**15 699**	**18 117**	**20 399**	**19 613**	**18 585**	**20 514**

[1] 121 kg and [2] 58 kg used in exported feed mixtures

2 Antimicrobial resistance in zoonotic bacteria

2.1 *Salmonella enterica* in domestic food-producing animals and food

The prevalence of *Salmonella* spp. in cattle, pigs and poultry as well as in meat and eggs is monitored through the national Salmonella control programme (23/EEO/1995; 20/EEO/2001, 1172/2009, 1173/2009). The objective of the programme is to maintain the annual incidence of salmonella contamination among food-producing animals and in the respective meat and eggs at 1% or below. The results of the programme show that salmonella is rare in food-producing animals and foods of animal origin in Finland. Salmonella isolates from the control programme are tested for antimicrobial susceptibility and included in the FINRES-Vet programme. Isolates from clinical cases and domestic food industry's in-house control systems are also included. 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 2019, 60 salmonella isolates from food-producing animals (including carcass samples) were tested for susceptibility. Most of the isolates originated from cattle (n=27) and pigs (n=25). Eight isolates originated from *Gallus gallus*. The most common serotypes were *S*. Derby (n=16), *S*. Typhimurium (n=12), monophasic *S*. Typhimurium (n=9) and *S*. Enteritidis (n=8). Other serotypes are shown in Appendix 4.

Resistance in salmonella from food-producing animals was overall low (Table 3). In 2019, multi-resistant monophasic *S*. Typhimurium was found in two calf rearing farms, one piglet-producing farm and four pig fattening farms. Monophasic *S*. Typhimurium isolates were resistant to ampicillin, sulfamethoxazole and tetracycline. This was the first time multi-resistant monophasic *S*. Typhimurium was found from food-producing animals in Finland.

Resistance situation of salmonella isolated from Finnish food-producing animals has been very favourable for a long time and multidrug resistance has overall been very rare (Figure 7). However, in recent years multiresistant *S.* Kentucky and monophasic *S.* Typhimurium has now also been detected among food-producing animals in Finland (FINRES-Vet 2018, Figure 7).

Table 3. *Distribution of MICs for Salmonella enterica in food-producing animals in 2019 (n=60).*

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	11.7	5.8-22.2							76.7	11.7						11.7				
Azithromycin	ND	-								8.3	78.3	13.3								
Cefotaxime	0.0	0.0-6.0					98.3	1.7												
Ceftazidime	0.0	0.0-6.0						98.3	1.7											
Chloramphenicol	0.0	0.0-6.0										93.3	6.7							
Ciprofloxacin	0.0	0.0-6.0	63.3	36.7																
Colistin	1.7	0.3-8.9							33.3	65.0	1.7									
Gentamicin	0.0	0.0-6.0						81.7	18.3											
Meropenem	0.0	0.0-6.0		85.0	13.3	1.7														
Nalidixic acid	0.0	0.0-6.0									88.3	11.7								
Sulfamethoxazole	13.3	6.9-24.2											36.7	40.0	8.3	1.7				13.3
Tetracycline	13.3	6.9-24.2								83.3	3.3			1.7		11.7				
Tigecycline	ND	-					95.0	5.0												
Trimethoprim	1.7	0.3-8.9					81.7	15.0	1.7						1.7					

Bold vertical lines indicate 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.
ND, not determined.

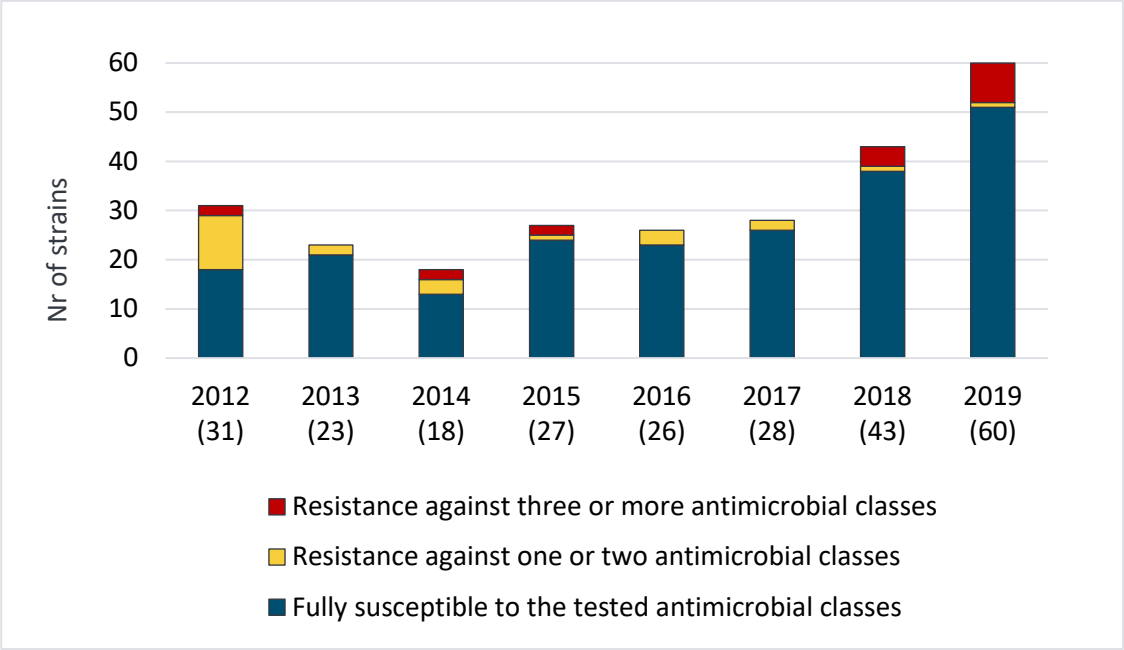

***Figure 7**. The number of sensitive and resistant salmonella isolates from food-producing animals in Finland in 2010–2019. Numbers of isolates tested each year are in brackets.*

2.2 *Campylobacter* spp. in food-producing and fur animals

In 2019, as in previous years, *Campylobacter jejuni* isolates from broilers were obtained from the national Campylobacter control programme and *C. jejuni* from fur animals were collected from diarrhoea samples sent to Finnish Food Authority.

2.2.1 *Campylobacter jejuni* from broilers

Within the national *Campylobacter* control programme of broilers in 2019, 48 *C. jejuni* isolates were tested for susceptibility, which also represents the number of campylobacter-positive broiler flocks in 2019. Of these, 7 (15%) were resistant to quinolones (ciprofloxacin, nalidixic acid) but resistance to the other studied antimicrobials was not detected (Table 4).

Table 4. *Distribution of MICs for Campylobacter jejuni from broilers in 2019 (n=48).*

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	14.6	7.2-27.3	70.8	12.5	2.1				12.5	2.1				
Erythromycin	0.0	0.0-7.6				100								
Gentamicin	0.0	0.0-7.6			52.1	47.9								
Nalidixic acid	14.6	7.2-27.3					12.5	62.5	8.3	2.1			14.6	
Streptomycin	0.0	0.0-7.6				12.5	85.4	2.1						
Tetracycline	0.0	0.0-7.6			100									

Bold vertical lines indicate 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.

Antimicrobial resistance in *Campylobacter* from broilers has been monitored systematically since 2003. Resistance levels in *C. jejuni* have been quite stable until the year 2013 and the occurrence of resistant isolates has been mainly at a low level (Figure 8). However, quinolone-resistant isolates have been more commonly detected since the year 2013. Between 2014 and 2018, the occurrence of quinolone resistance has been more common every other year with the previous peaks observed in 2014, 2016 and 2018. In 2014 and 2016, quinolone resistance was commonly accompanied with tetracycline resistance. However, in 2018 and 2019, tetracycline resistance was not observed. The proportion of isolates resistant to erythromycin, gentamicin or streptomycin has remained low or non-existent throughout the surveillance period. Further, the percentage of isolates susceptible to all studied antimicrobials has varied between 75% and 100%, with the lowest percentage in 2014 and 2018 paralleling the highest occurrence of quinolone resistance (Figure 9). Multidrug resistance to the tested antimicrobials has not been detected.

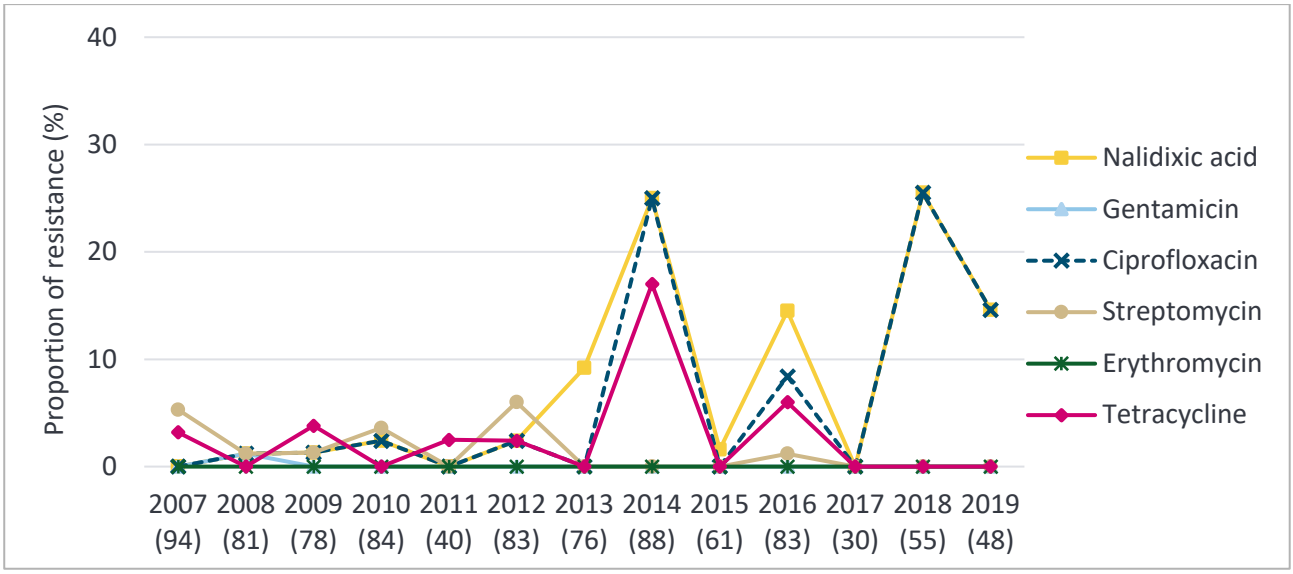

Figure 8*. The proportions of resistant Campylobacter jejuni isolates from broilers at slaughter in Finland between the years 2007 and 2019. Numbers of isolates tested each year are in brackets.*

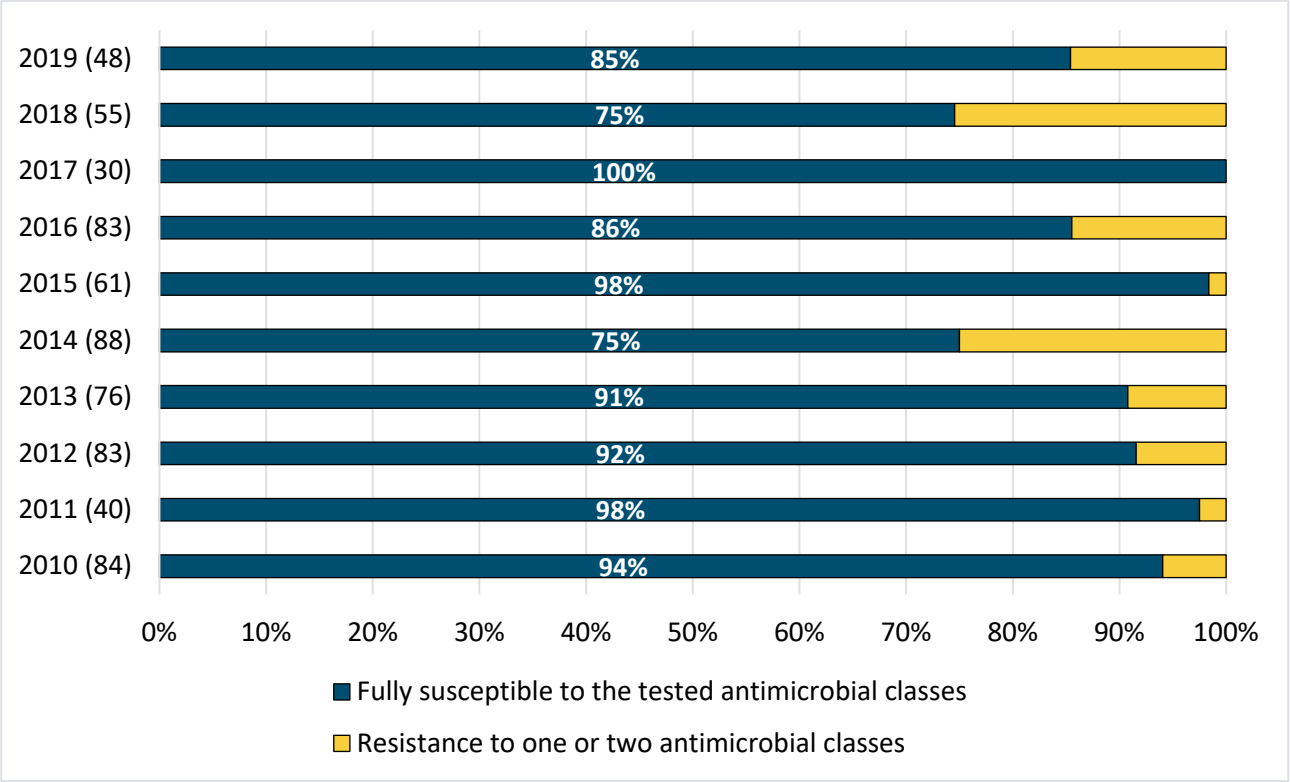

Figure 9. *Antimicrobial susceptibility of Campylobacter jejuni isolated from broilers at slaughter in Finland between the years 2010 and 2019. Numbers of isolates tested each year are in brackets.*

2.2.2 *Campylobacter jejuni* from fur animals

Campylobacter spp. are isolated from fur animals as part of diarrhoea examination, mostly from farmed fox and to a lesser extent from mink. *Campylobacter jejuni* infections in fur animals are treated with antimicrobials and these bacteria pose also a risk to the farmers. Resistance data from fur animals has been included in the previous FINRES-Vet reports in 2016–2017 and 2018.

In 2019, the occurrence of quinolone and tetracycline resistance remained at similar levels compared to the previous year being moderate against quinolones and low against tetracycline (Figure 10). When interpreting the MIC distributions using clinical breakpoints, the only difference was a lower percentage of isolates resistant to tetracycline (3.6% vs 7.1%; Table 5).

Over the monitoring period, occurrence of isolates resistant against tetracycline has decreased from high to low level while occurrence of quinolone resistance has remained relatively stable at moderate level. Resistance to streptomycin has been observed seldom and, similarly to broilers, no resistance against erythromycin or gentamicin has been detected.

Table 5. *Distribution of MICs for Campylobacter jejuni from fur animals in 2019 (n=56).*

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	12.5	6.2-23.6	83.9	3.6					5.4	5.4	1.8			
Erythromycin	0.0	0.0-6.4				100								
Gentamicin	0.0	0.0-6.4		14.3	80.4	5.4								
Nalidixic acid	12.5	6.2-23.6					7.1	73.2	7.1			1.8	10.7	
Streptomycin	0.0	0.0-6.4			7.1	51.8	35.7	5.4						
Tetracycline	7.1	2.8-17.0			92.9		1.8		1.8	1.8	1.8			

Bold vertical lines indicate 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.

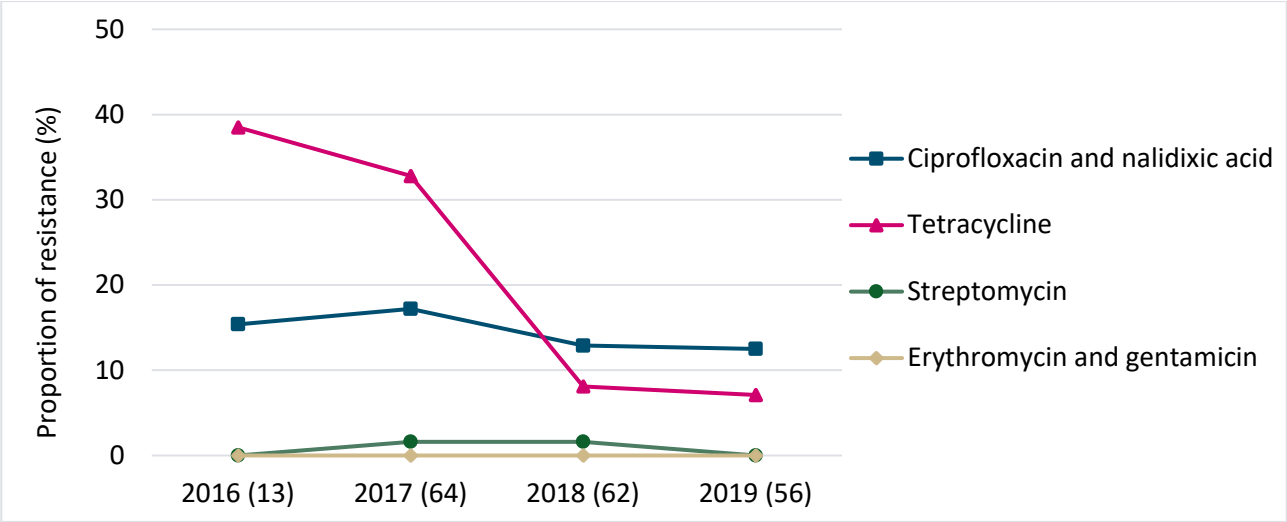

Figure 10. *The proportions of resistant Campylobacter jejuni isolates from fur animals in Finland between the years 2016 and 2019. Numbers of isolates tested each year are in brackets.*

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 (Commission Decision 2013/652/EU). In Finland, these bacteria are screened from broilers, cattle and pigs, as well as meat thereof, targeting pigs, pork and beef in 2019. 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. The details of the methodology are described in Appendix 3.

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

In 2019, extended-spectrum beta-lactamase (including AmpC beta-lactamase) producing *E. coli* were screened from pig caecal samples (n=288) collected at slaughterhouses and from fresh pork (n=306) and beef (n=297) samples collected at retail. From pigs, ESBL- or AmpC-producing *E. coli* was isolated from 2.4% (7/288) of the caecal samples in 2019 (Table 6). The prevalence of ESBL/AmpC-producing *E. coli* in pigs has been in the same level also in 2015 and 2017.

The majority of the meat samples (pork, beef) have been of domestic origin, and all samples were fresh and without added ingredients. In 2019, ESBL- or AmpC-producing *E. coli* were isolated only from two beef samples, both were of non-domestic origin (Table 6). ESBL/AmpC-producing *E. coli* have been very rare in pork and beef in all the studied years in 2015, 2017 and 2019. Carbapenemase-producing *E. coli* was not detected in any of the samples.

Table 6. *Results of the specific screening of ESBL-, AmpC- and carbapenemase-producing E. coli in food-producing animals and meat in 2015, 2017 and 2019.*

Year	Sampling stage	Nr of samples	Nr (%) of ESBL[1]	Nr (%) of AmpC[1]	Nr of CP-EC[2]	% ESBL/AmpC
Pigs						
2015	at slaughter	306	1 (0.3%)	8 (2.6%)	0	2.9%
2017	at slaughter	299	1 (0.3%)	7 (2.3%)	0	2.7%
2019	at slaughter	288	1 (0.3%)	6 (2.1%)	0	2.4%
Pork						
2015	at retail	303	0 (0%)	1 (0.3%)	0	0.3%
2017	at retail	301	0 (0%)	0 (0%)	0	0%
2019	at retail	306	0 (0%)	0 (0%)	0	0%

Year	Sampling stage	Nr of samples	Nr (%) of ESBL[1]	Nr (%) of AmpC[1]	Nr of CP-EC[2]	% ESBL/AmpC
Beef						
2015	at retail	300	0 (0%)	0 (0%)	0	0%
2017	at retail	302	0 (0%)	0 (0%)	0	0%
2019	at retail	297	2 (0.7%)[3]	0 (0%)	0	0.7%

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

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

[3] both findings were of non-domestic origin

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

In 2019, liners of transport boxes of 38, five 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 7). Positive flocks were not detected in any of the groups.

Over the prior screening period of 2013–2019, none of the tested turkey flocks have been found to harbour ESBL/AmpC-producing *E. coli* whereas the proportion of positive flocks has fluctuated between 0 to 75% for both the imported broiler and the chicken egg production chains. Carbapenemase-producing *E. coli* have not been detected. In 2018 and 2019, all the tested imported poultry flocks appear to be free also from ESBL/AmpC-producing *E. coli* and thus the situation is very favourable for the Finnish poultry industry.

Table 7. *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 2013–2019.*

Imported poultry flocks	2013	2014	2015	2016	2017	2018	2019
For broiler meat production							
Nr of sampled flocks	4	37	54	62	37	42	38
Nr of ESBL positive flocks	2	1	1	0	0	0	0
Nr of AmpC positive flocks	2	3	9	24	8	0	0
Nr (%) of ESBL/AmpC positive flocks	3 (75%)	4 (11%)	10 (19%)	24 (39%)	8 (22%)	0 (0%)	0 (0%)
For turkey production							
Nr of sampled flocks	5	5	6	5	4	5	5
Nr of ESBL positive flocks	0	0	0	0	0	0	0
Nr of AmpC positive flocks	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%)
For egg production							
Nr of sampled flocks	3	6	4	3	4	5	3
Nr of ESBL positive flocks	0	1	1	0	0	0	0
Nr of AmpC positive flocks	1	3	2	0	3	0	0
Nr (%) of ESBL/AmpC positive flocks	1 (33%)	4 (67%)	3 (75%)	0 (0%)	3 (75%)	0 (0%)	0 (0%)

4 Antimicrobial 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 swine 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 from sampling, isolation procedures and susceptibility testing are described in Appendix 3.

4.1 *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, 50 *E. coli* isolates from 27 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 antimicrobial usage.

The MIC distributions and the resistance percentages using epidemiological cut-off values are given in Table 8. As before, resistance was commonly detected against ampicillin, fluoroquinolones, tetracycline, streptomycin, sulfamethoxazole and trimethoprim. Resistance against 3rd generation cephalosporins was detected in four isolates from two farms, from which two isolates from one farm were phenotypically AmpC. No ESBL-producers were detected. Resistance to chloramphenicol was low. In 2019, no resistance to florfenicol was detected. No resistance has been detected against colistin or gentamicin between 2016 and 2019.

Between 2016 and 2019, no dramatic changes can be seen in resistance levels to the tested antimicrobials (Figures 11 and 12) using epidemiological cut-off values. As in previous years, multidrug resistance (resistance to ≥3 antimicrobial classes) was commonly detected. Notably, in 2019 the proportion of fully susceptible isolates has slightly decreased while the proportion of isolates resistant to one or two antimicrobial classes has increased. The proportion of multidrug-resistant isolates has been about the same during these years (Figure 11). In 2019, seventeen isolates from twelve different farms were multidrug resistant when both epidemiological and clinical breakpoints were applied. Note that for fluoroquinolones (enrofloxacin), interpretation of resistance using clinical breakpoints differs the most compared to the epidemiological cut-off values (Table 8).

Table 8. *Distribution of MICs for Escherichia coli from porcine enteritis in 2019 (n=50). Resistance percentage is the proportion of resistance calculated with epidemiological cut-off values.*

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	26.0	15.9-39.6							20.0	54.0				10.0			16.0			
Cefotaxime[1]	6.4	2.2-17.2			36.2	36.2	21.3	2.1	4.3											
Ceftazidime[2]	7.0	2.4-18.6					51.2	41.9	2.3	4.7										
Chloramphenicol	6.0	2.1-16.2								6.0	72.0	16.0		6.0						
Ciprofloxacin	22.0	12.8-35.2	10.0	60.0	8.0	10.0	8.0	4.0												
Colistin	0.0	0.0-7.1						62.0	36.0	2.0										
Enrofloxacin	14.0	7.0-26.2			76.0	10.0	4.0	10.0												
Florfenicol	0.0	0.0-7.1									58.0	42.0								
Gentamicin	0.0	0.0-7.1						88.0	12.0											
Nalidixic acid	22.0	12.8-35.2								56.0	22.0			8.0	6.0	8.0				
Streptomycin	32.0	20.8-45.8									50.0	16.0	2.0	4.0	10.0	18.0				
Sulfamethoxazole	36.0	24.1-49.9										46.0	18.0							36.0
Tetracycline	46.0	33.0-59.6							44.0	10.0				14.0	6.0	10.0	16.0			
Trimethoprim	28.0	17.4-41.7				28.0	22.0	10.0	8.0	4.0				28.0						
Trim/sulfa[3]	28.0	17.4-41.7						70.0	2.0			28.0								

Bold vertical lines indicate epidemiological cut-off values for resistance. Dotted vertical lines indicate clinical breakpoints for susceptibility (left dotted vertical line) and resistance (right dotted vertical line). Clinical breakpoints are given only if they are available and differ from the epidemiological cut-off values. 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=47

[2] n=43

[3] concentration of trimethoprim given, tested with sulfamethoxazole in concentration ratio of 1:20

Clinical resistance was also commonly detected to all antimicrobial classes that can be used to treat *E. coli* infections in pigs (sulfonamide-trimethoprim, tetracycline, aminopenicillins and fluoroquinolones). Multidrug resistance was also common. Attention should be paid to the fact that enteritis in pigs can be caused by multidrug resistant *E. coli* bacteria. This emphasises the importance of diagnostic samples in order to determine the farm-specific resistance profiles of enterotoxigenic *E. coli*. To avoid further selection of antimicrobial resistance, only efficient drugs should be used in the treatment of *E. coli* diarrhoea in pigs.

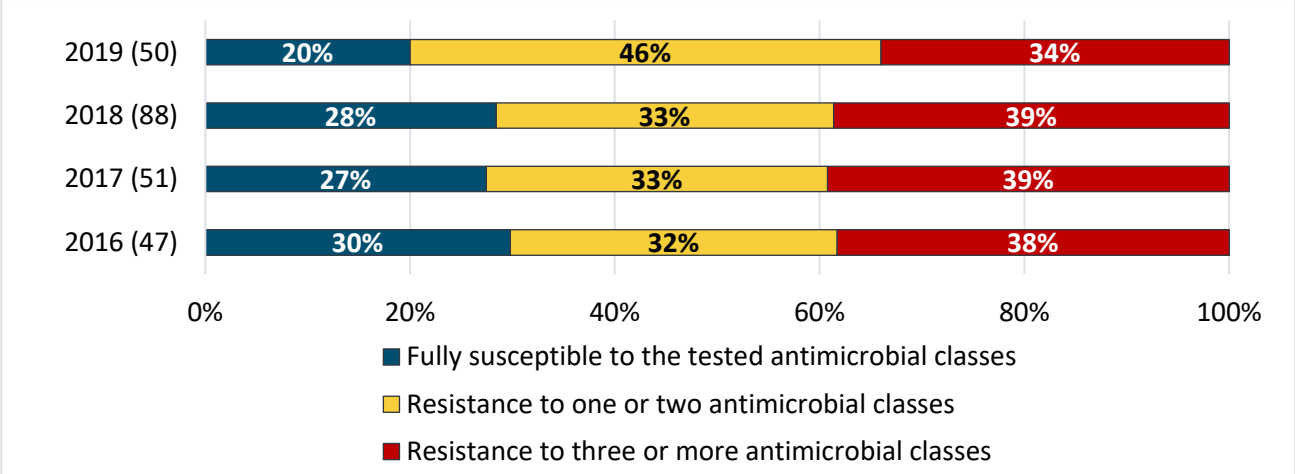

***Figure 11**. The proportions of multidrug resistant E. coli isolates from porcine enteritis in years 2016–2019, epidemiological cut-off values used. Numbers of isolates tested each year are in brackets.*

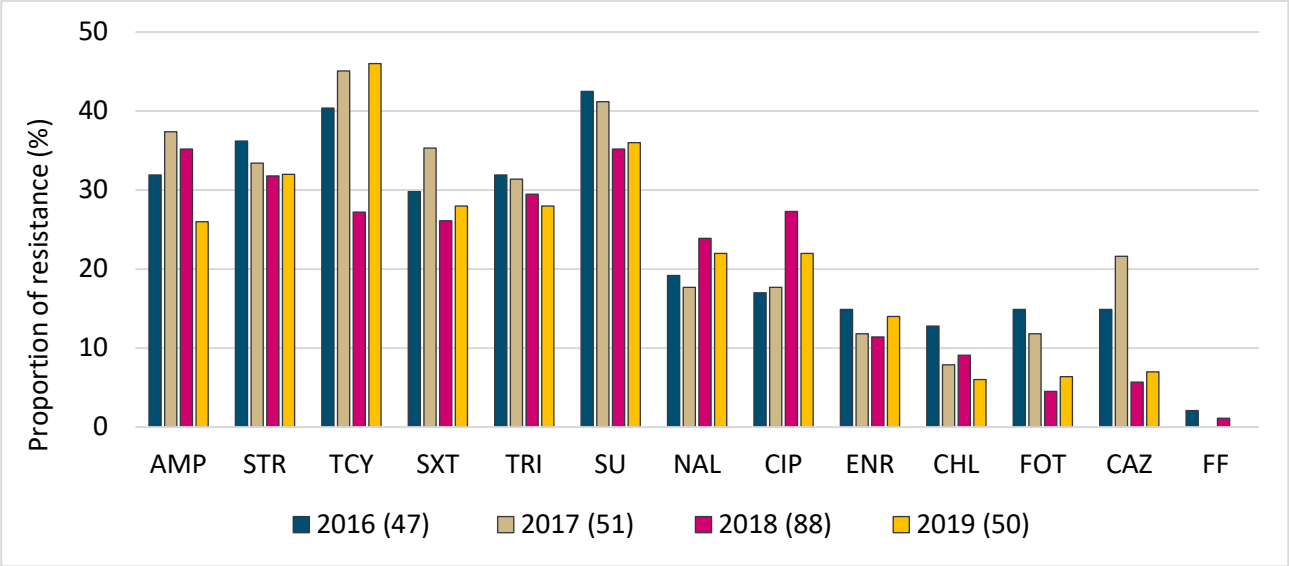

***Figure 12**. Resistance to tested antimicrobials in years 2016–2019, epidemiological cut-off values. Numbers of isolates tested each year are in brackets.*

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

4.2 *Actinobacillus pleuropneumoniae* from respiratory diseases of pigs

A. pleuropneumoniae is the most important respiratory pathogen in growing pigs in Finland. In 2019, altogether 35 isolates from 30 farms was tested for antimicrobial susceptibility. All obtained isolates were included. As in previous years, intermediate susceptibility against oxytetracycline was common (Table 9). No resistance against tiamulin, tulathromycin, florfenicol or ceftiofur was detected. Between 2016 and 2019, no significant changes in the MICs for the tested substances can be seen. Each year the number of tested isolates is rather small.

Table 9. *Distribution of MICs for Actinobacillus pleuropneumoniae from pigs in 2019 (n=35).*

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	0.0-9.9		94.3	5.7								
Ceftiofur	0.0	0.0-9.9		97.1	2.9								
Penicillin[1]	0.0	0.0-9.9	28.6	42.9	28.6								
Oxytetracycline	0.0	0.0-9.9			82.9	17.1							
Tiamulin	0.0	0.0-9.9							25.7	74.3			
Tulathromycin	0.0	0.0-9.9							5.7	48.6	45.7		

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 breakpoint not available

4.3 *Brachyspira pilosicoli* from pigs

There are no standardised breakpoints established for *Brachyspira pilosicoli* from pigs. As a guide for the choice of antimicrobial for treatment of spirochaetal diarrhoea, a clinical breakpoint for tiamulin of > 1 mg/L, for tylosin of >2 mg/L, for valnemulin of >1 mg/L and for lincomycin of >4 mg/L were used in Finland in 2019. With these breakpoints, 5% of the isolates were resistant to tiamulin, 62% of the isolates were resistant to tylosin and 19% to lincomycin (Table 10). No resistance against valnemulin was detected. Resistance in *B. pilosicoli* has been at the same level from 2015 to 2019, although the number of isolates tested each year was too small to draw any definite conclusions.

Table 10. *Distribution of MICs for Brachyspira pilosicoli from pigs in 2019 (n=21).*

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			76.2	14.3	4.8		4.8							
Lincomycin					61.9	4.8	9.5	4.8	4.8	9.5	4.8			
Tiamulin		61.9	14.3	19.0					4.8					
Tylosin							38.1	28.6	4.8	9.5		9.5		9.5
Tylvalosin					14.3	47.6	23.8	4.8		4.8		4.8		
Valnemulin	61.9	9.5	19.0	4.8	4.8									

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.

4.4 *Histophilus somni*, *Pasteurella multocida* and *Mannheimia haemolytica* from bovine respiratory diseases

During 2019, the number of farms sending samples for respiratory disease diagnostics rose compared to the three previous years. One isolate per submission (and from each compartment if more than one was sampled) and per bacterial species was selected for susceptibility testing. *H. somni* isolates were obtained from 37 farms and except one farm, all others had fully susceptible isolates to all antimicrobials tested. *H. somni* isolates resistant to oxytetracycline was found in one farm. The MIC distributions of different antimicrobials in *H. somni* are shown in Table 11.

Pasteurella multocida isolates were obtained from 165 farms and 92.7% of them had fully susceptible isolates. On one farm, multidrug resistant *P. multocida* (resistant to penicillin, oxytetracycline and florfenicol) and on another farm, strains resistant to penicillin and oxytetracycline were found. On eight farms, isolates resistant to only oxytetracycline, on one farm only to penicillin and on one farm only to tulathromycin were found. *Mannheimia haemolytica* isolates were obtained from 67 farms and 91% of them had fully susceptible isolates. Resistance to penicillin decreased and to oxytetracycline increased compared to year 2018. The MIC distributions of different antimicrobials in *P. multocida* and *M. haemolytica* are shown in Tables 12 and 13, respectively.

Table 11. *Distribution of MICs for Histophilus somni from bovine respiratory disease in 2019 (n=40).*

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	0.0-8.8		100									
Enrofloxacin	0.0	0.0-8.8	100										
Florfenicol	0.0	0.0-8.8		100									
Oxytetracycline	7.5	2.6-19.9			92.5						7.5		
Penicillin	0.0	0.0-8.8	97.5	2.5									
Tulathromycin	0.0	0.0-8.8				10.0	32.5	45.0	12.5				

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.

Table 12. *Distribution of MICs for Pasteurella multocida from bovine respiratory disease in 2019 (n=267).*

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	0.0-1.4		100									
Enrofloxacin	0.0	0.0-1.4	100										
Florfenicol	0.4	0.1-2.1		55.8	43.8					0.4			
Oxytetracycline	7.9	5.2-11.7			71.9	10.1	10.1		0.4	7.5			
Penicillin	1.5	0.6-3.8	98.1	0.4		0.4			0.4	1.1			
Tulathromycin	1.1	0.4-3.3				70.8	25.1	1.1	1.5	0.4			1.1

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.

Table 13. *Distribution of MICs for Mannheimia haemolytica from bovine respiratory disease in 2019 (n=79).*

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	0.0-4.6		100									
Enrofloxacin	0.0	0.0-4.6	100										
Florfenicol	0.0	0.0-4.6			75.9	24.1							
Oxytetracycline	5.1	2.0-12.3			87.3	6.3	1.3			5.1			
Penicillin	10.1	5.2-18.7	48.1	32.9	8.9	2.5			1.3	6.3			
Tulathromycin	0.0	0.0-7.4					57.0	43.0					

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.

4.5 *Escherichia coli* from colibacillosis in broilers

Since 2014, colibacillosis has been a major problem in broiler production in Nordic countries including Finland. In 2017, a vaccination program with an autogen vaccine against two major serotypes was started in some broiler chains and the colibacillosis situation appears to be significantly better in 2019. Colibacillosis infections in broilers or broiler parents are not treated with antimicrobials in Finland. The *E. coli* isolates were obtained from both parent and production flocks in cases of clinical colibacillosis. In 2019, 27 isolates representing 25 different flocks and 18 different holdings were studied. Based on epidemiological cut-off values, resistance to ampicillin was low, and resistance to sulfamethoxazole and tetracycline was moderate in 2019 (Table 14). Only single isolates resistant against 3rd generation cephalosporins were found in 2016 and 2017 (FINRES-Vet 2016–2017) but not at all in 2018 (FINRES-Vet 2018) or 2019. The occurrence of resistance against different antimicrobials has varied annually (Figure 13) which is probably due to small number of tested isolates.

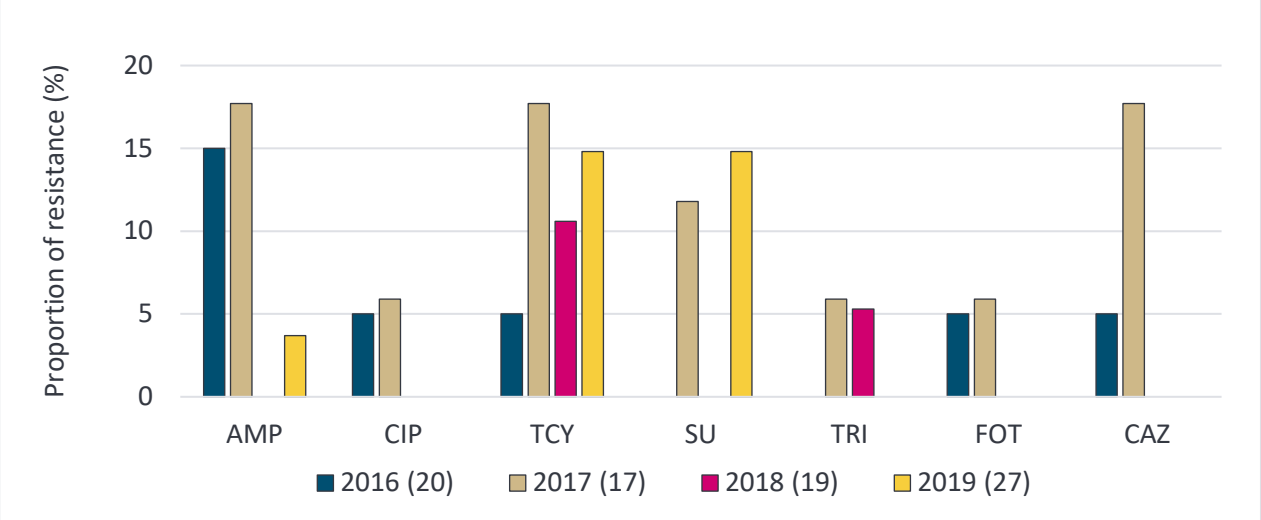

***Figure 13**. Resistance to tested antimicrobials among E. coli from colibacillosis in the years 2016–2019, epidemiological cut-off values. Numbers of isolates tested each year are in brackets.*
AMP, ampicillin; CIP, ciprofloxacin, TCY; tetracycline; SU, sulfamethoxazole; TRI, trimethoprim, FOT, cefotaxime; CAZ, ceftazidime.

Table 14. *Distribution of MICs for Escherichia coli from colibacillosis in 2019 (n=27).*

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	3.7	0.7-18.3								59.3	37.0				3.7					
Cefotaxime	0.0	0.0-12.5			63.0	29.6	7.4													
Ceftazidime	0.0	0.0-12.5					92.6	7.4												
Ciprofloxacin	0.0	0.0-12.5	74.1	22.2	3.7															
Colistin	0.0	0.0-12.5						7.4	85.2	7.4										
Sulfamethoxazole	14.8	5.9-32.5										40.7	44.4							14.8
Tetracycline	14.8	5.9-32.5							25.9	55.6	3.7				3.7	11.1				
Trimethoprim	0.0	0.0-12.5					37.0	59.3	3.7											

Bold vertical lines indicate 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.

4.6 *Staphylococcus aureus* from tenosynovitis in broilers

Staphylococcus aureus from broiler tenosynovitis cases were isolated from clinical and post-mortem samples submitted to Finnish Food Authority. All obtained *S. aureus* isolates were included. Eighteen isolates from eight farms representing twelve different flocks were studied. All isolates were susceptible to the reported antimicrobials (Table 15). No isolates were found to produce beta-lactamase and no MRSA isolates were found. Tenosynovitis is occasionally treated with antimicrobials in broiler parent flocks and only a small number of flocks are treated. Production flocks have not been treated with antimicrobials since 2010 (Animal Health ETT ry).

Table 15. *Distribution of MICs for Staphylococcus aureus from tenosynovitis in broilers in 2019 (n=18).*

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	0.0-17.6	7.0			5.6			5.6	88.9				
Penicillin[1]	0.0	0.0-17.6	88.9	11.1										
Tetracycline	0.0	0.0-17.6					100							
Trim/sulfa[2]	0.0	0.0-17.6			100									

Bold vertical lines indicate 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 profiles based on beta-lactamase production

[2] concentration of trimethoprim given, tested with sulfamethoxazole in concentration ratio of 1:20

5 Antimicrobial resistance in animal pathogens from companion animals and horses

Antimicrobial 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, antimicrobial resistance corresponds to the proportion of resistant and intermediate isolates. The reporting period covers data from January 2014 to December 2019 and includes solely bacterial isolates derived from clinical infections. Screening samples for resistant bacteria (MRSA, MRSP, ESBL) were omitted from the analysis. Approximately 33% of specimens were from the Veterinary Teaching Hospital of the University of Helsinki and 67% 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.

5.1 *Staphylococcus aureus* from companion animals and horses

Antimicrobial resistance level in *S. aureus* of dogs, cats and horses was low (Figure 14), except for penicillin (not shown in figure). In 2019, 119 isolates were investigated for penicillinase production and 68% of them tested positive, which is comparable to the previous year (67%).

In general, oxacillin resistance (indicating the presence of MRSA) remained generally at a low level during the monitoring period, ranging between 0–9%, being approximately 6% in 2019. Of the seven MRSA isolates detected in 2019, four isolates were from dogs and three others from horses. The four canine isolates were of *spa* types t034 (two isolates), t304 and t223. During 2019, an outbreak of MRSA CC398 (*spa* t011) was ongoing in the Equine Teaching Hospital of the University of Helsinki. While there were many cases of nosocomial colonization, only singular infections were noted.

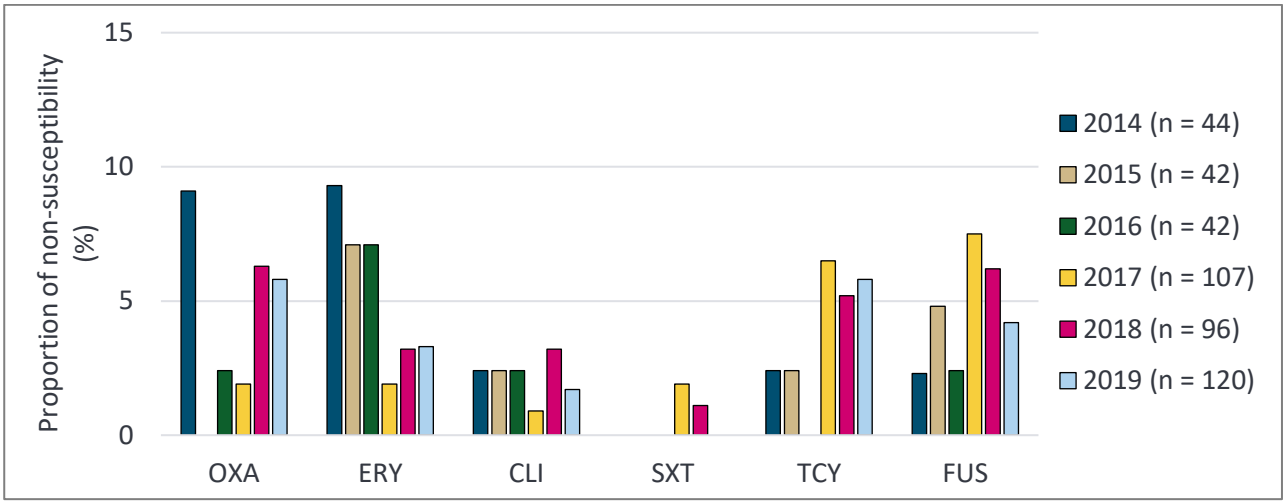

***Figure 14**. Antimicrobial non-susceptibility (%) in canine, feline and equine S. aureus in 2014–2019. The numbers of tested isolates are in brackets.*
OXA, oxacillin; ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline; FUS, fusidic acid.

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 be a zoonotic bacterium and may thus have an impact on public health. While most clinical findings were from dogs, the large-scale nosocomial spread of the bacterium among horses is of concern. The horse stable environment may not provide horse owners, care givers and hobbyists the necessary tools to prevent the zoonotic spread of MRSA.

5.2 *Staphylococcus pseudintermedius* from dogs

The proportion of MRSP isolates, as indicated by oxacillin non-susceptibility, increased slightly in 2019 (7.3%) compared to 2018. The resistance level had already been decreasing earlier: it was moderate (12–14%) in 2014-2016, but then decreased to 9% in 2017, and further down to 6% in 2018 (Figure 15). Penicillinase production remained high as out of the 797 tested *S. pseudintermedius* isolates in 2019, 88% produced penicillinase, which is a much larger proportion than among *S. aureus* isolates.

The overall resistance level of *S. pseudintermedius* remained similar in 2019 when compared to the few previous years (Figures 15 and 16). There was a slight decrease in macrolide (erythromycin) and lincosamide (clindamycin) resistance, non-susceptibility having been approximately 21% for both antimicrobial 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 27%. Three strains expressed intermediate susceptibility to amikacin.

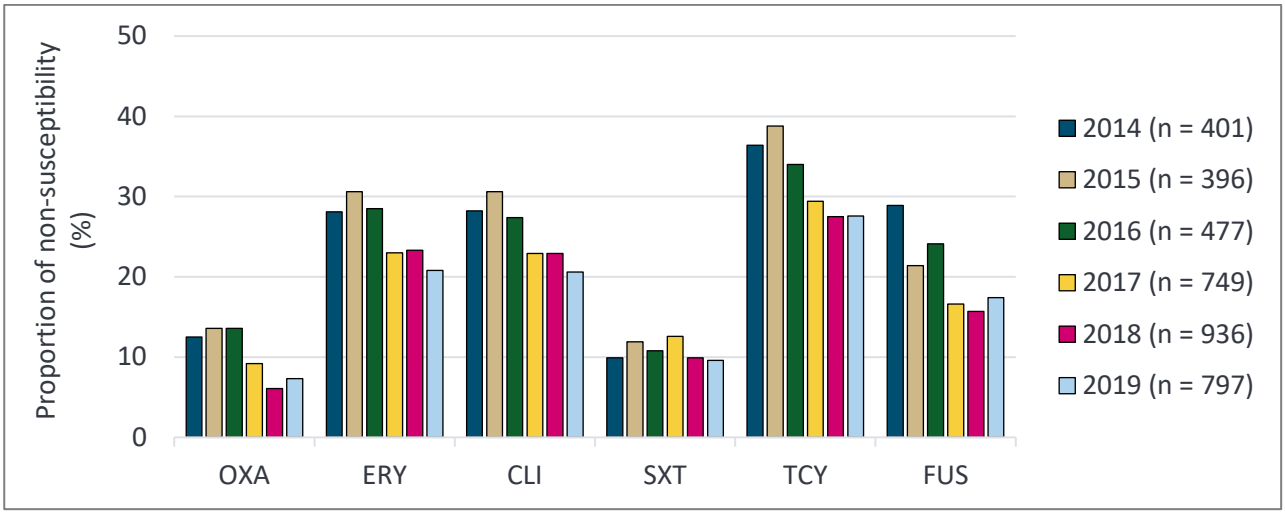

***Figure 15**. Antimicrobial non-susceptibility (%) for primary antimicrobial agents in canine S. pseudintermedius isolates in 2014–2019. The numbers of tested isolates are in brackets.*
OXA, oxacillin; ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline; FUS, fusidic acid

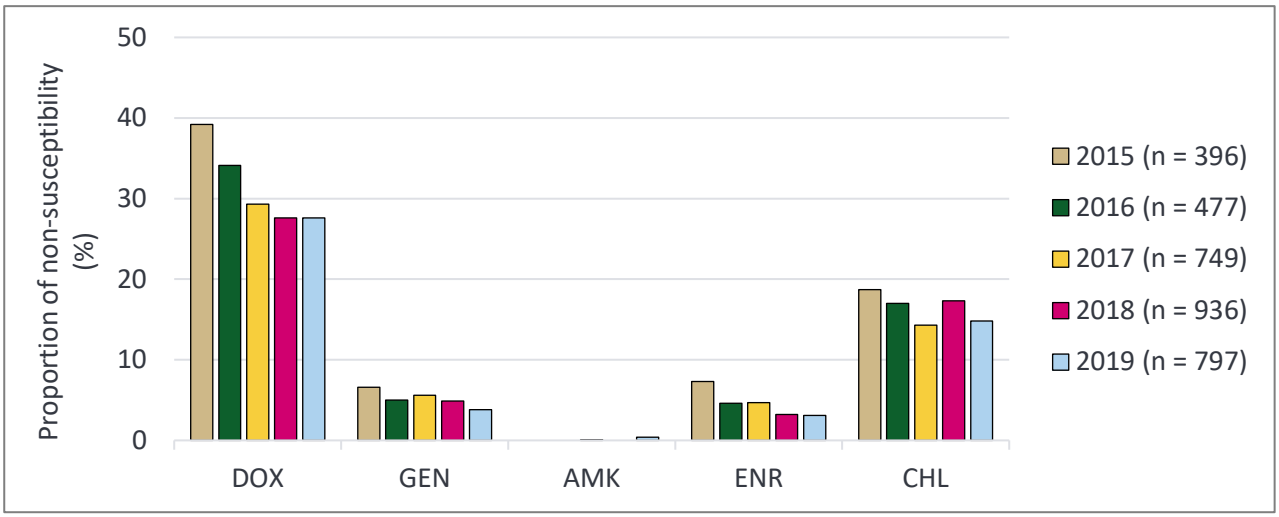

***Figure 16**. Antimicrobial non-susceptibility (%) for secondary antimicrobial agents in canine S. pseudintermedius isolates in 2015–2019. The numbers of tested isolates are in brackets. The year 2014 was omitted due to small number of tested isolates.*
DOX, doxycycline; GEN, gentamicin; AMK, amikacin; ENR, enrofloxacin; CHL, chloramphenicol

S. pseudintermedius belongs to the normal microbiome of the skin and mucous membranes in dogs and more rarely in cats. It is an opportunistic pathogen that most often causes skin or wound infections and occasionally urinary tract infections. Although the proportion of oxacillin resistance and thus the proportion of MRSP among *S. pseudintermedius* isolates has increased slightly 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, 88% of the isolates produced penicillinase, which is a significant proportion. A penicillinase-producing isolate is resistant to many commonly used beta-lactam antibiotics, such as

ampicillin, amoxicillin and penicillin. 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. *S. pseudintermedius* is a moderately common urinary pathogen in dogs.

5.3 *Escherichia coli* from dogs and cats

Resistance figures for canine and feline *E. coli* are presented in Figure 17 and 18, respectively. While resistance rates in canine *E. coli* continued to decline for some antibiotics, ampicillin resistance increased from 37% in 2018 to 47% in 2019, which is closer to the 2017 figure. It may be that 2018 represented a statistical anomaly as no other explanation was identified. In feline isolates, ampicillin resistance remained similar. Amoxicillin-clavulanic acid non-susceptibility was analogous for both cats and dogs and persisted from the previous year.

Enrofloxacin resistance in canine *E. coli* isolates decreased during the last five years, having been under 6% in 2019. Sulfonamide-trimethoprim resistance in canine and feline *E. coli* fluctuated through the monitoring period, having been 11% in dogs and 2% in cats in 2019.

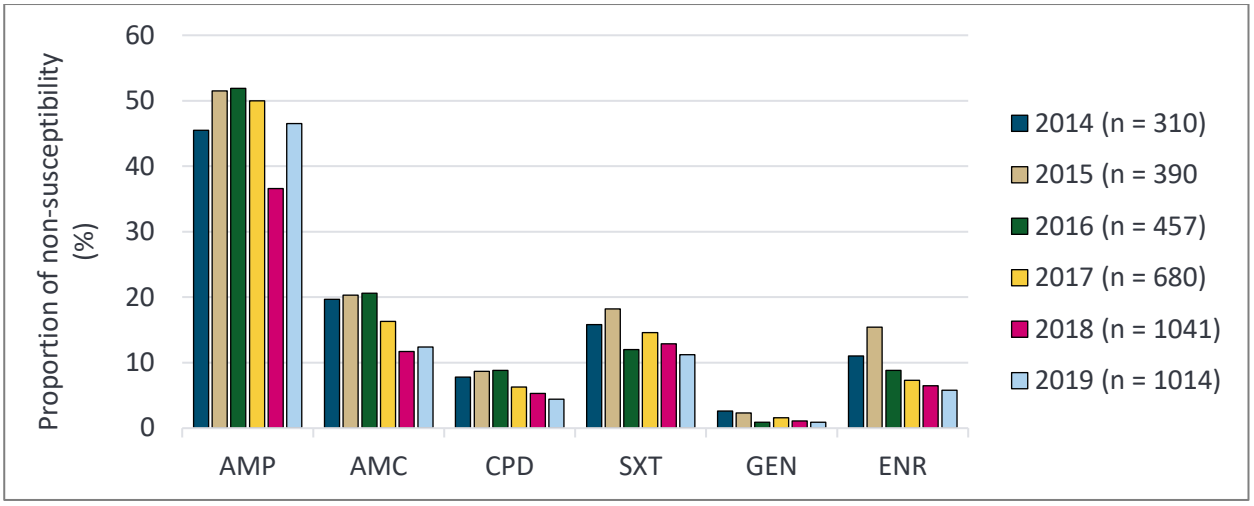

***Figure 17**. Antimicrobial non-susceptibility (%) in canine E. coli in 2014–2019. The numbers of tested isolates are in brackets.*

AMP, ampicillin; AMC, amoxicillin-clavulanic acid; CPD, cefpodoxime; SXT, trimethoprim-sulfamethoxazole; GEN, gentamicin; ENR, enrofloxacin

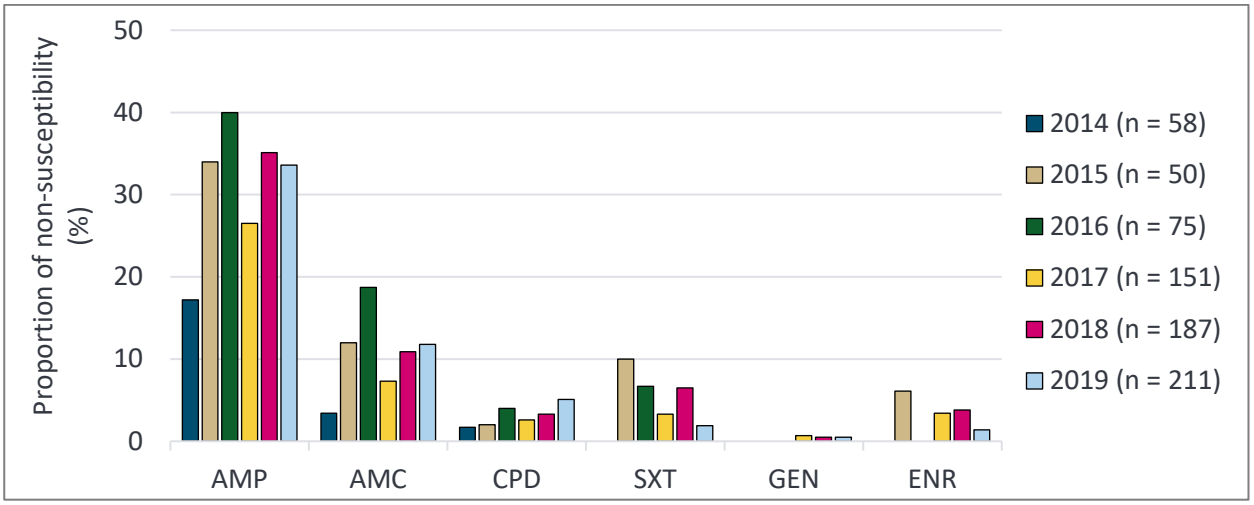

***Figure 18**. Antimicrobial non-susceptibility (%) in feline E. coli in 2014–2019. The numbers of tested isolates are in brackets.*

AMP, ampicillin; AMC, amoxicillin-clavulanic acid; CPD, cefpodoxime; SXT, trimethoprim-sulfamethoxazole; GEN, gentamicin; ENR, enrofloxacin

In 2019, 4.4% of canine *E. coli* were resistant to cefpodoxime, indicating reduced susceptibility to third generation cephalosporins, with a downward drift from 2016 (Figure 19). The proportion of ESBL and AmpC producing isolates continued to decrease in 2019, having been 0.9% and 2.7%, respectively. In 2019, the proportion of ESBL-producing *E. coli* isolates was 0.9% also in cats. While the proportion of feline *E. coli* resistant to third-generation cephalosporins increased to its highest level in five years, resistance to sulfonamide-trimethoprim and enrofloxacin decreased. The increase in cefpodoxime resistance was mainly due to AmpC-producing isolates, which were found more frequently compared to previous years. In 2019, the proportion was 4.2%, whereas in 2018, it was only 1.6%.

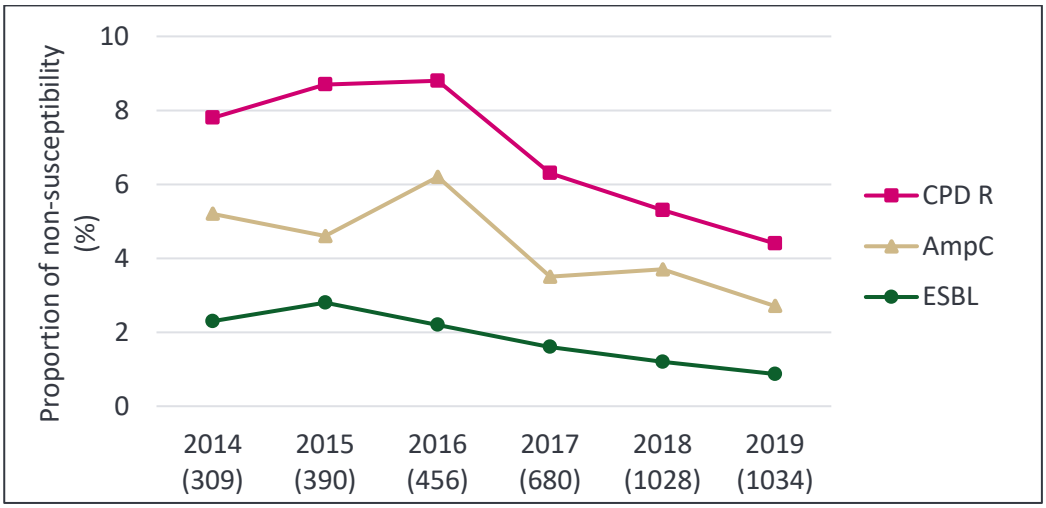

***Figure 19.** Proportion of isolates with reduced susceptibility to cefpodoxime (CPD), and proportion of ESBL and AmpC positive isolates in canine E. coli in 2014–2019. The numbers of isolates tested against CPD are in brackets. Only CPD resistant (CPD R) isolates were tested for phenotypic ESBL/AmpC production.*

CPD, cefpodoxime; AmpC and ESBL, extended-spectrum beta-lactamases

5.4 Streptococci from dogs and horses

In 2019, all of the tested canine *Streptococcus canis* isolates (283) were susceptible to penicillin and nearly all to trimethoprim-sulfamethoxazole (Figure 20). Resistance to erythromycin and clindamycin somewhat increased, but tetracycline resistance increased drastically, by nearly 20 percentage points. 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 was much larger.

In 2019, 56 equine *Streptococcus equi* ssp. *zooepidemicus* isolates were tested. All of the isolates were susceptible to penicillin. For trimethoprim-sulfamethoxazole, the decreasing figure in the proportion of resistant strains continued: in 2017, 12% of the isolates expressed resistance, but in 2019 the number was only 4%. Even though the change has been favourable, the development of resistance to this antimicrobial substance still has to be monitored carefully due to the importance of it in the treatment of many equine infections.

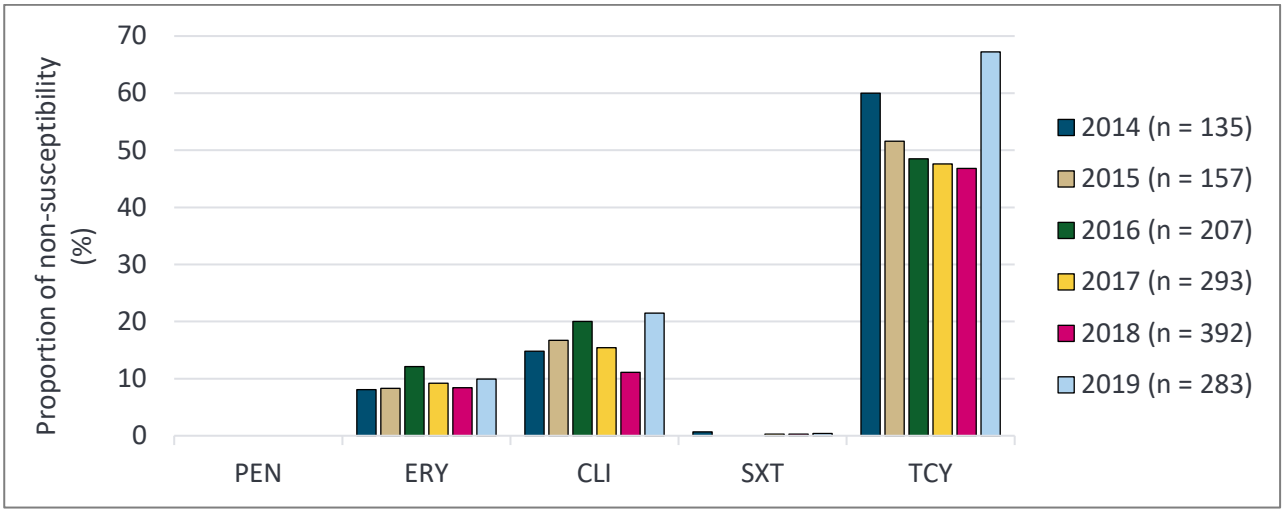

***Figure 20**. Antimicrobial non-susceptibility (%) in canine S. canis isolates in 2014–2019. The numbers of tested isolates are in brackets (in 2019, 351 isolates were tested for tetracycline susceptibility).*
PEN, penicillin; ERY, erythromycin; CLI, clindamycin; SXT, trimethoprim-sulfamethoxazole; TCY, tetracycline

5.5 *Pseudomonas aeruginosa* from dogs

In 2019, 105 isolates of canine *P. aeruginosa* were tested. Overall, the strains were quite susceptible to all tested antimicrobials, as noted in 2018. Only one percent of the isolates expressed amikacin resistance, and 5% were non-susceptible to gentamicin. No resistance to polymyxin B or tobramycin was detected. Most isolates (87%) were susceptible to ciprofloxacin. For enrofloxacin, 78% of isolates were non-susceptible, of which 28%-points were resistant.

6 Antimicrobial resistance in indicator bacteria from food-producing animals

Resistance to 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 antimicrobials used in the animal population. In this report, the results of the indicator *E. coli* from slaughtered pigs are presented. Details of the sampling and laboratory analysis are described in Appendix 3.

6.1 Indicator *E. coli* from pigs

In 2019, a total of 174 isolates from pigs were tested for antimicrobial susceptibility to 14 antimicrobials. The majority (77.6%) of the isolates was fully susceptible to the tested antimicrobial classes (Figure 22). The most common resistance traits detected were against tetracycline (14%), sulfamethoxazole (13%), ampicillin (9%), and trimethoprim (9%) (Table 16). Altogether, 8% of the isolates were multiresistant in 2019. The most commonly detected resistance profile in the multiresistant isolates in 2019 was resistance against sulfamethoxazole, tetracycline and trimethoprim (n=4) (Table 17). Also, one AmpC isolate was detected.

The proportion of resistant isolates to tetracycline has continuously decreased from 2013 reaching the lowest level since 2004 (Figure 21). Also, resistance to trimethoprim has decreased since 2015 while the proportion of resistant isolates to ampicillin and sulfamethoxazole were similar than in 2017. Resistance to ciprofloxacin was low (1.7%). Since June 2019, a Finnish health care register for swine farms (Sikava) regulated the use of fluoroquinolones and 3rd generation cephalosporins on pig farms belonging to a national classification level in Finland (Sikava, 2019). These antimicrobial classes can only be used in individual cases when Sikava's specialised veterinarian has authorised it based on the results of antimicrobial susceptibility testing.

Table 16. *Distribution of MICs for indicator Escherichia coli in pigs in 2019 (n=174).*

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	9.2	5.7-14.4							4.6	35.1	46.6	4.6				9.2				
Azithromycin	ND	ND								8.0	59.2	32.8								
Cefotaxime	0.6	0.1-3.2					99.4			0.6										
Ceftazidime	0.6	0.1-3.2						99.4				0.6								
Chloramphenicol	1.7	0.6-4.9										97.1	1.1	1.1	0.6					
Ciprofloxacin	1.7	0.6-4.9	87.9	9.8	0.6		1.1	0.6												
Colistin	0.0	0.0-2.2							83.3	16.7										
Gentamicin	0.0	0.0-2.2						67.2	32.2	0.6										
Meropenem	0.0	0.0-2.2		99.4	0.6															
Nalidixic acid	1.7	0.6-4.9									97.1	1.1	0.6			1.1				
Sulfamethoxazole	12.6	8.5-18.4										67.8	19.0	0.6						12.6
Tetracycline	13.8	9.4-19.7								82.8	3.4			0.6	4.6	8.6				
Tigecycline	0.0	0.0-2.2					99.4	0.6												
Trimethoprim	8.0	4.9-13.1					55.7	33.3	2.3	0.6					8.0					

Bold vertical lines indicate 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.
ND, not determined

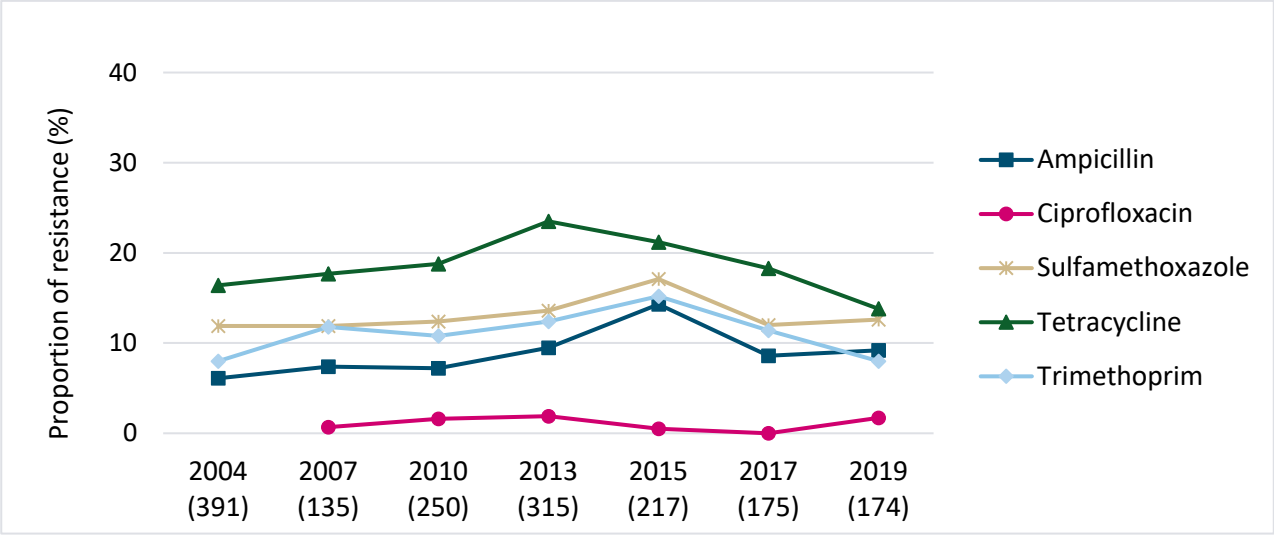

***Figure 21**. Resistance in indicator E. coli from pigs to selected antimicrobials in 2004–2019. The numbers of tested isolates each year are in brackets.*

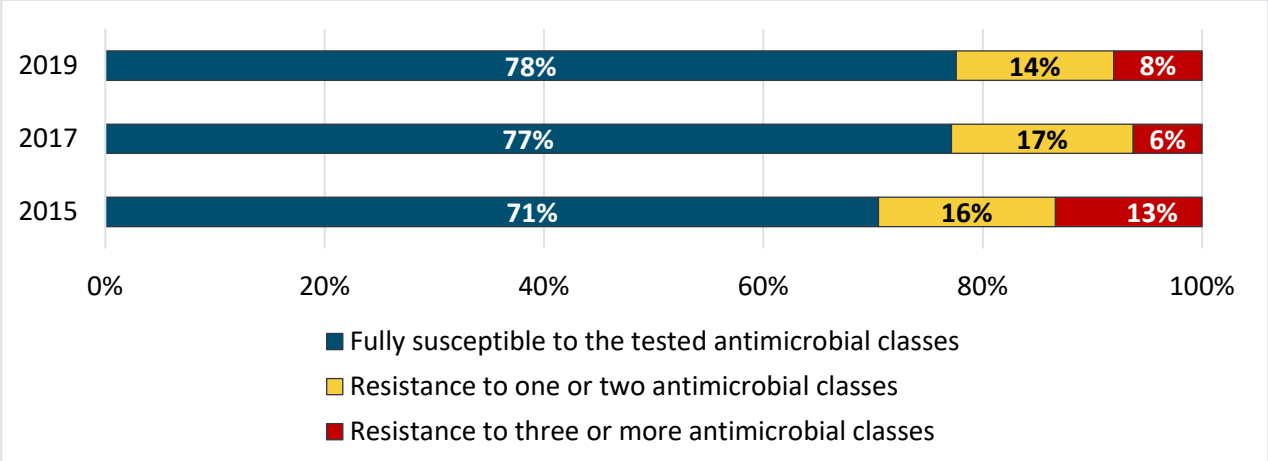

***Figure 22**. Antimicrobial susceptibility of indicator E. coli from pigs at slaughter in Finland between the years 2015 and 2019. The numbers of tested isolates each year are the same as in Figure 21.*

***Table 17**. Detected resistance profiles among indicator E. coli from pigs in 2015, 2017 and 2019.*

Resistance profile	Nr of isolates in each year		
	2015	2017	2019
AMP-TET-SU-TRI-CIP-NAL-CHL			**1**
AMP-TET-SU-TRI-CHL-GEN	**1**		
AMP-TET-SU-TRI	**12**	**5**	**3**
TET-SU-TRI-NAL		**1**	
AMP-SU-TRI-CHL		**1**	
TET-SU-TRI-GEN	**1**		
TET-SU-TRI	**9**	**7**	**4**
AMP-SU-TRI	**4**	**2**	**1**
AMP-TET-SU	**1**	**1**	**3**
AMP-TET-TRI	**1**	**1**	
TET-SU-CIP-NAL			**1**
SU-TRI-CHL			**1**
AMP-TET	6	3	
AMP-SU	2	2	4
TET-SU	1		
TET-CIP-NAL	1		1
SU-TRI	3	1	2
TET-TRI		1	1
AMP-CAZ-FOT[1]			1
AMP-TRI	1		
SU-CHL			1
TET	13	13	10
AMP	3		3
SU	3	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 18. The number of livestock and farms, and the production of meat and milk in Finland are presented in Tables 19–22 (Source: Luke, the Natural Resources Institute Finland).

***Table 18**. Population of food-producing animals as PCU (1000 tonnes) by species in 2010–2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle	227	227	224	224	226	229	228	222	220	213
Pigs	182	182	171	170	163	163	161	153	142	142
Poultry	60	62	65	67	68	70	73	76	82	83
Sheep and goats	10	11	11	11	11	13	13	13	13	12
Horses	30	30	30	30	30	30	30	30	30	30
Fish	12	11	13	14	13	15	14	15	14	15
TOTAL, PCU	520	522	514	516	512	520	520	508	500	496

***Table 19.** Number of livestock (in thousands) in Finland in 2010–2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Dairy cows	289	286	284	283	285	285	282	275	271	262
Suckler cows	55	57	58	57	58	59	59	60	60	60
Cattle > 1 year[1]	278	273	268	271	268	264	258	261	252	247
Calves < 1 year	303	299	303	300	303	307	310	297	299	288
TOTAL, Cattle	926	914	913	912	914	915	909	893	882	858
Boars and sows	154	146	136	128	123	NA[2]	NA	NA	NA	NA
Pigs > 20 kg	804	797	779	815	760	NA	NA	NA	NA	NA
Piglets < 20 kg	409	392	375	365	362	NA	NA	NA	NA	NA
TOTAL, pigs	1 367	1 335	1 290	1 308	1 245	1 243	1 235	1 136	1 089	1 072
Laying hens	3 394	3 304	3 173	3 432	3 645	3 595	3 599	3 746	3 985	3 900
Chicks	838	745	743	858	714	662	748	509	608	647
Broilers	4 616	5 421	6 038	6 861	7 341	7 827	8 272	8 047	8 781	9 112
Turkeys	280	308	295	274	292	246	260	292	299	263
Other poultry[2]	459	457	512	555	584	597	566	543	468	438
TOTAL, poultry	9 587	10 236	10 761	11 981	12 577	12 927	13 445	13 136	14 140	14 360

[1] Heifers and bulls in total

[2] Including broiler hens

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 20. *Number of farms in Finland in 2010–2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle farms total	15 641	14 919	14 141	13 416	12 885	12 389	11 791	11 175	10 530	9 851
Pig farms total	2 078	1 917	1 747	1 637	1 486	1 337	1 240	1 102	1 027	963
Poultry farms total	1 304	1 314	1 155	1 207	1 299	1 310	1 300	1 280	1 243	1 172

Source: OFS: Luke, Number of livestock.

Table 21*. The production of meat and fish (million kg) in Finland in 2010–2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Beef[1]	82	83	80	80	82	86	86	85	87	87
Pork[1]	203	202	193	194	186	192	190	182	169	171
Poultry[1]	96	102	107	111	113	117	125	129	135	139
Total	383	387	382	387	383	397	403	397	391	398
Fish[2]	12	11	13	14	13	15	14	15	14	15

[1] In slaughterhouses; [2] for human consumption, ungutted

Source: OFS: Luke, Meat production and Aquaculture.

Table 22. *The production of milk in Finland in 2010–2019.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Milk production; per animal (litres)	7 896	7 859	7 876	7 977	8 201	8 323	8 406	8 534	8 650	8 810
Total milk production (million litres)	2 268	2 234	2 230	2 260	2 330	2 365	2 359	2 336	2 328	2 305

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

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

Table 23. *Overall sales of veterinary antimicrobials in Finland 2010–2019, kg active ingredient.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018[1]	2019
Tetracyclines	1 728	1 838	1 759	2 389	2 576	2 250	2 010	2 268	2 218	2 677
Amphenicols	59	124	61	121	84	80	87	104	112	117
Penicillin G	5 162	5 010	4 784	4 721	4 502	4 332	3 773	4 018	4 055	3 854
Aminopenicillins	1 317	1 284	1 342	1 314	1 374	1 498	1 438	1 160	1 020	1 011
Cloxacillin	114	112	97	82	91	65	63	45	39	33
1st gen. cephalosporins	906	1 056	902	793	753	605	513	355	284	227
3rd gen. cephalosporins	5	9	15	8	8	7	3	1	0,5	0,2
Sulfonamides and trimethoprim[1]	3 274	3 045	3 149	3 129	2 893	2 445	2 460	2 216	1 870	2 119
Macrolides	572	532	575	456	521	596	517	408	411	221
Lincosamides	202	164	179	155	189	165	120	297	184	197
Aminoglycosides	166	128	108	103	101	93	87	73	61	59
Fluoroquinolones	96	102	107	105	113	94	99	80	81	66
Pleuromutilins	48	73	66	43	44	30	23	14	10	3
Total sales	13 651	13 475	13 144	13 419	13 250	12 262	11 192	11 037	10 344	10 585

[1] Sales of sulfonamides and trimethoprim in 2018 corrected

Table 24. *Sales of injectable veterinary antimicrobials in Finland 2010–2019, kg active ingredient.*

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Tetracyclines	527	515	521	558	552	640	686	671	642	741
Amphenicols	0	12	13	26	17	6	13	26	15	23
Penicillin G	5 023	4 849	4 552	4 542	4 243	4 047	3 450	3 777	3 804	3 713
Aminopenicillins	440	404	434	379	416	473	453	338	286	279
1st gen. cephalosporins	0	0	0	0	0	0	5	1	1	0
3rd gen. cephalosporins	5	9	15	8	8	7	3	1	0,5	0,2
Sulfonamides and trimethoprim	329	297	360	344	358	373	322	317	286	292
Macrolides	13	13	11	12	12	15	19	13	10	9
Lincosamides	40	30	27	24	26	26	25	19	18	19
Aminoglycosides	19	18	20	12	15	13	14	12	10	10
Fluoroquinolones	78	85	84	83	90	72	78	63	66	50
Total sales of injectables	6 472	6 230	6 036	5 990	5 737	5 672	5 069	5 238	5 139	5 136

***Table 25**. Sales of orally administered veterinary antimicrobials (premixes, oral solutions, oral powders, oral pastes and tablets) in Finland 2010–2019, kg active ingredient*

	2010	2011	2012	2013	2014	2015	2016	2017	2018[1]	2019
Tetracyclines	1 202	1 323	1 237	1 830	2 024	1 610	1 324	1 597	1 575	1 936
Amphenicols	59	112	48	95	67	74	74	78	97	94
Penicillin G	0	17	110	47	122	147	190	100	105	0
Aminopenicillins	856	860	893	923	947	1017	976	813	728	728
1st gen. cephalosporins	872	1025	871	766	730	587	493	341	274	219
Sulfonamides and trimethoprim[1]	2 945	2 747	2 789	2 784	2 535	2 072	2 138	1 899	1 584	1 828
Macrolides	559	519	565	444	510	581	498	395	402	212
Lincosamides	161	134	152	130	164	139	94	278	165	178
Aminoglycosides	95	79	76	76	70	62	54	41	32	29
Fluoroquinolones	19	17	23	22	22	22	22	16	15	15
Pleuromutilines	48	73	66	43	44	30	23	14	10	3
Total sales of orally adm. products	6 816	6 906	6 829	7 160	7 236	6 342	5 885	5 571	4 986	5 244

[1] Sales of sulfonamides and trimethoprim in 2018 corrected

***Tables 26A and 26B.** Sales of intramammaries for veterinary use in Finland 2010–2019, kg active ingredient*

26A. Intramammaries for lactation phase

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Penicillin	104	107	94	94	100	94	85	92	98	93
Aminopenicillins	15	14	11	8	8	7	7	6	5	3
Cephalexin	29	30	31	27	22	18	15	13	9	8
Cloxacillin	60	56	47	39	41	31	29	19	18	15
Aminoglycosides	29	12	1	0	0	0	0	0	0	0
Macrolides	1	1	0	0	0	0	0	0	0	0
Total lactation phase	**237**	**220**	**185**	**168**	**170**	**150**	**136**	**129**	**129**	**119**

26B. Intramammaries for dry cow treatment

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Penicillin	35	38	28	38	37	44	47	50	48	48
Aminopenicillins	6	6	5	4	3	2	2	3	1	0
Cephalexin	6	1	0	0	0	0	0	0	0	0
Cloxacillin	55	55	49	43	50	35	34	26	21	18
Aminoglycosides	24	20	12	16	15	18	19	20	20	20
Total dry cow	**126**	**120**	**94**	**101**	**106**	**98**	**102**	**100**	**90**	**86**

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 system.

Campylobacter jejuni were collected from broilers in association with the Finnish Campylobacter control programme for broilers. 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. All isolates (one isolate per slaughter batch) are included in the antimicrobial susceptibility testing.

Campylobacter spp. from fur animals were isolated from intestinal or faecal samples as part of diarrhoea examination.

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 Evira. All obtained *S. aureus* isolates were included from the study period. *A. pleuropneumoniae* isolates originate 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 are from post-mortem samples from parent or production pedigree, and isolated either from bone marrow or heart. *Brachyspira pilosicoli* isolates are from faecal samples of swine with diarrhoea.

Antimicrobial 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 2014–2019.

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

Indicator *E. coli* was isolated from pig caeca in 2019. From the same samples, the screening of ESBL/AmpC and carbapenemase producing *E. coli* was done. The samples from broilers (n=288) originated from healthy animals at slaughter between February and December. The sampling was evenly distributed throughout the study period. The number of randomly taken samples from each slaughterhouse was proportional to the

annual slaughter volume. The pig slaughterhouses accounted approximately for 98% of the total number of slaughtered fattening pigs in Finland.

From each farm, sample was taken from one animal. The samples were taken aseptically and transported refrigerated to the laboratory within two days. Samples were mainly collected between Monday and Thursday.

Indicator *E. coli* isolates tested for susceptibility were randomly selected from all isolates available at the laboratory. Each isolate represented a different epidemiological unit (farm).

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

Randomly selected samples of packed fresh and chilled (not frozen) meat from pigs (n=306) and bovines (n=297) were collected at retail between February and December in 2019. Altogether, 277 meat samples from pigs and 287 meat samples from bovines were of domestic origin. 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. The meat samples were sliced or diced and wrapped in vacuum or in a controlled atmosphere.

The samples were transported refrigerated to the laboratory within 1 day. The temperature of the meat was measured at the laboratory at arrival. From the biggest NUTS-3 area, samples were also collected on Fridays and transported to the laboratory during the same day. One isolate from each epidemiological unit (if available) was selected for susceptibility testing.

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 from broilers were isolated at slaughterhouse laboratories and confirmed at Finnish Food Authority, Microbiology Unit, according to ISO 10272-1:2017.

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.

Indicator E. coli

Intestinal 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

The screening of ESBL/AmpC and carbapenemase producing *E. coli* from pigs was done from the same samples (n=288) as the isolation of indicator *E. coli*. Also, meat samples from pigs (n=306) and bovines (n=297) were screened as part of the EU-wide monitoring based on Commission Decision 2013/652/EU according to the 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).

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-A4. The susceptibility testing of animal pathogens was performed with a broth microdilution method using VetMIC™ (Department of Antibiotics, National Veterinary Institute, Uppsala, Sweden) or Sensititre™ (TREK Diagnostic Systems Ltd, United Kingdom) microtiter plates. The susceptibility of salmonella and indicator *E. coli* was performed using Sensititre™ plates. The susceptibility of campylobacter was performed using VetMIC™ plates. 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™ EUVSEC2 plates (salmonella, indicator *E. coli and* isolates from the ESBL/AmpC screening). Beta-lactamase activity in *S. aureus* was tested with Cefinase™ 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 (October 2020) 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 27). When available, clinical breakpoints of the current CLSI documents (CLSI VET08, 2018 or CLSI M100, 2019) were used to evaluate clinical resistance. There are no standardised breakpoints approved for *Brachyspira* spp. from swine. Clinical cut-off values (Rønne at al. 1990) were applied to *B. pilosicoli* MICs.

Table 27. *Epidemiological cut-off values (mg/L) used in this report.*

Substance	*Salmonella enterica*	*Escherichia coli*	*Campylobacter jejuni*	*Campylobacter coli*	*Staphylococcus aureus*
Ampicillin	>8	>8			
Cefotaxime	>0.5	>0.25			
Cefoxitin					>4
Ceftazidime	>2	>0.5			
Chloramphenicol	>16	>16			
Ciprofloxacin	>0.06	>0.06	>0.5	>0.5	
Colistin	>2 [1]	>2			
Enrofloxacin		>0,125			
Erythromycin			>4	>8	
Florfenicol	>16	>16			
Gentamicin	>2	>2	>2	>2	
Meropenem	>0.125	>0.125			
Nalidixic acid	>8	>8	>16	>16	
Streptomycin	>16	>16	>4	>4	
Sulfamethoxazole	>256 [1]	>64			

Substance	*Salmonella enterica*	*Escherichia coli*	*Campylobacter jejuni*	*Campylobacter coli*	*Staphylococcus aureus*
Tetracycline	>8	>8	>1	>2	>1
Trimethoprim	>2	>2			
Trimethoprim/ sulfamethoxazole[2]		>1[3]			>0.25[4]

[1] no ECOFF available

[2] concentration of trimethoprim given, concentration ratio with sulfamethoxazole 1:20

[3] differs from ECOFF

[4] tentative 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 standard (CLSI VET01-A4). For all data, clinical breakpoints of the standard CLSI VET01-S2 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-S24 (2014) was used. An exception was the fucidic acid non-susceptibility breakpoint, which was ≤ 23 (FiRe-standard, version 6). Beta-lactamase activity was tested with Cefinase™ 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 antimicrobial 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 VetMIC™ and/or Sensititre™ 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 2019

Table 28. *Salmonella enterica serovars isolated from the main food-producing animal species in Finland in 2019.*

Serotype	Nr of isolates	Cattle	Pigs	Poultry (Gallus gallus)	Turkeys
S. Derby	16		16		
S. Typhimurium	12	5	2	5	
monophasic *S.* Typhimurium	9	3	6		
S. Enteritidis	8	7	1		
S. Altona	5	5			
S. Infantis	4	4			
S. Diarizonae	2	2			
S. Abony	1			1	
S. Adelaide	1			1	
S. Bredeney	1			1	
S. Umbilo	1	1			

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