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The European Union Summary Report on Antimicrobial Resistance in zoonotic and indicator bacteria from humans, animals and food in 2018/2019

European Food Safety Authority and
European Centre for Disease Prevention and Control

Abstract

Data on antimicrobial resistance (AMR) in zoonotic and indicator bacteria from humans, animals and food are collected annually by the EU Member States (MSs), jointly analysed by the EFSA and the ECDC and reported in a yearly EU Summary Report. The annual monitoring of AMR in animals and food within the EU is targeted at selected animal species corresponding to the reporting year. The 2018 monitoring specifically focussed on poultry and their derived carcases/meat, while the monitoring performed in 2019 specifically focused on pigs and calves under 1 year of age, as well as their derived carcases/meat. Monitoring and reporting of AMR in 2018/2019 included data regarding *Salmonella*, *Campylobacter* and indicator *Escherichia coli* isolates, as well as data obtained from the specific monitoring of presumptive ESBL-/AmpC-/carbapenemase-producing *E. coli* isolates. Additionally, some MSs reported voluntary data on the occurrence of meticillin-resistant *Staphylococcus aureus* in animals and food, with some countries also providing data on antimicrobial susceptibility. This report provides an overview of the main findings of the 2018/2019 harmonised AMR monitoring in the main food-producing animal populations monitored, in related carcase/meat samples and in humans. Where available, data monitoring obtained from pigs, calves, broilers, laying hens and turkeys, as well as from carcase/meat samples and humans were combined and compared at the EU level, with particular emphasis on multidrug resistance, complete susceptibility and combined resistance patterns to critically important antimicrobials, as well as *Salmonella* and *E. coli* isolates possessing ESBL-/AmpC-/carbapenemase phenotypes. The outcome indicators for AMR in food-producing animals such as complete susceptibility to the harmonised panel of antimicrobials in *E. coli* and the prevalence of ESBL-/AmpC-producing *E. coli* have been also specifically analysed over the period 2015–2019.

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Summary

In **2018–2019**, data on antimicrobial resistance in zoonotic and indicator bacteria, submitted by 28 EU Member States (MSs), were jointly analysed by the EFSA and the ECDC. Resistance in zoonotic *Salmonella* and *Campylobacter* from humans, animals and food, as well as resistance in indicator *Escherichia coli* and meticillin-resistant *Staphylococcus aureus* (MRSA) from animals and food were addressed. 'Microbiological' resistance was assessed using epidemiological cut-off (ECOFF) values; for some countries, qualitative data on human isolates were interpreted in a way which corresponds closely to the ECOFF-defined 'microbiological' resistance.

In *Salmonella* spp. from human cases in 2019, resistance to ampicillin, sulfonamides and tetracyclines was observed at overall high levels, while resistance to third-generation cephalosporins was noted at overall low levels of 1.8% and 1.2% for cefotaxime and ceftazidime, respectively. A decline in resistance to ampicillin and tetracyclines in isolates from humans was observed in eight and 11 countries, respectively, over the period 2015–2019, particularly evident in *S.* Typhimurium and its monophasic variant, serovars commonly associated with pigs and calves. In *Salmonella* spp. and indicator *E. coli* isolates recovered from animals and food during the 2018–2019 routine monitoring, resistance to ampicillin, tetracyclines and sulfonamides was also frequently detected and resistance to third-generation cephalosporins was uncommon; paralleling that observed in *Salmonella* isolates reported from human cases. Additionally, resistance to (fluoro)/quinolones was very high/high levels among *Salmonella* spp. and indicator *E. coli* isolates recovered from broilers, fattening turkeys and poultry carcases/meat in 2018. In *Salmonella* spp. isolates from human cases, a moderate occurrence of resistance to ciprofloxacin was observed in 2019 but among S. Kentucky isolates, extremely high prevalence of resistance at 82.1% was noted and in S. Enteritidis, increasing trends in resistance were observed in eight countries over the period 2015–2019, both serovars predominantly being associated with poultry.

The monitoring included assessment of the levels of presumptive extended-spectrum beta-lactamase (ESBL)-/AmpC-/carbapenemase-producers among *Salmonella* spp. from human cases, food-producing animals and animal carcases; as well as among indicator *E. coli* isolates from food-producing animals. At the reporting MS group level, the proportion of presumptive ESBL or AmpC producers was low among all indicator *E. coli* isolates recovered from the animal sector (fattening pigs, calves, broilers and fattening turkeys) and very low to low among *Salmonella* spp. recovered from animals/carcases (broilers, laying hens, fattening turkeys, fattening pigs and carcases of broilers and fattening pigs) and from human cases, although higher in some *Salmonella* serovars. Within both the routine and specific monitoring (non-selective and selective media, respectively), varying occurrence/prevalence rates of presumptive ESBL or AmpC producers were observed in different reporting countries. Carbapenemase-producing *E. coli* were detected in five samples from fattening pigs in four MSs, in one sample from meat from pigs in one MS and one sample of meat from bovine animal in one non-MSs in 2019 – findings are provisional as two strains need to be confirmed; while no presumptive or confirmed carbapenemase-producing *E. coli* was detected from broilers and their derived meat in 2018. Only one *Salmonella* isolate was identified as cabapenemase-producing from human cases in 2019 (a *S.* Typhimurium var. O5- carrying bla_{OXA-48} isolated from a domestically acquired infection) compared with five in 2018.

Resistance to colistin was uncommon among *Salmonella* spp. and *E. coli* isolates recovered from food-producing animals (fattening pigs, calves, *Gallus gallus* and fattening turkeys) and carcases/meat derived from these animals, although moderate resistance was notably observed in certain *Salmonella* serovars.

In *Campylobacter* from humans, food-producing animals and poultry meat, the occurrence of resistance to ciprofloxacin and tetracycline generally ranged from high to extremely high, particularly in *C. coli* isolates from humans and from poultry and derived meat. Erythromycin resistance was much lower in *C. jejuni* but moderate in *C. coli* isolates from humans, turkeys and pigs. Ciprofloxacin resistance increased over the period 2015–2019 in *C. jejuni* from humans in nine countries, while erythromycin resistance decreased in five. Overall combined resistance to both ciprofloxacin and erythromycin, which are considered critically important for treatment of campylobacteriosis, was generally rare to low in *C. jejuni* from humans, poultry and calves, and low to moderate in *C. coli* from humans, poultry and pigs. Notably, moderate to high proportions of *C. jejuni* from poultry, moderate to high proportions of *C. coli* from poultry and pigs and high to extremely high proportions of *C. coli* from humans, were co-resistant to ciprofloxacin and erythromycin in some countries.

Combined resistance to critically important antimicrobials in *Salmonella* and *E. coli* from both humans and animals was uncommon, although very high to extremely high occurrence of multidrug resistance was observed in certain *Salmonella* serovars. Notably, *S.* Infantis accounted for most of the multidrug-resistant *Salmonella* spp. recovered from broilers and their derived carcases (79% and 75.3%, respectively), and monophasic *S.* Typhimurium accounted for 56.5% and 56.4% of the multidrug-resistant *Salmonella* spp. recovered from fattening pigs and their derived carcases, respectively. Furthermore, *Salmonella* Kentucky accounted for most of the *Salmonella* isolates from both humans in 2019 and poultry in 2018, which exhibited high-level resistance to ciprofloxacin (92/106 and 180/252 isolates, respectively), in addition to the detection of third-generation cephalosporin resistance in some isolates.

The voluntary monitoring of MRSA from food and healthy animals in 2018–2019 revealed that most MRSA isolates, where typing data were available, were livestock-associated (LA-) MRSA (97.6% in 2018 and 98.2% in 2019). However, spa-types classified as community-associated (CA-) and healthcare-associated (HA-) MRSA were also reported, as well as those carrying the *mecC* gene (a variant of the meticillin resistance gene, mecA). The occasional detection of lineages of CA- and HA-MRSA primarily associated with humans is presumably due to the sporadic interchange of strains between humans and animals. A significant observation from the monitoring includes the detection of linezolid-resistant strains harbouring the *cfr* gene from fattening pigs in 2019. Since linezolid is an important compound in human medicine for the treatment of MRSA, establishing whether linezolid resistance is widespread or more localised in distribution in MRSA in animals is highly relevant. The probable detection of CA-MRSA USA300 from pig and cattle meat in 2019 is another important finding, as this strain can cause severe infections in humans and has a markedly different epidemiology from HA-MRSA strains.

The outcome indicators for AMR in food-producing animals, such as complete susceptibility to the harmonised panel of antimicrobials in *E. coli* and the prevalence of ESBL-/AmpC-producing *E. coli* have also been specifically analysed over the period 2015–2019. There are marked variations in both outcome indicators among reporting countries. A positive development manifested by statistically significant decreasing trends in the prevalence of ESBL-/AmpC-producing *E. coli* in food-producing animals is observed in 14 countries (13 MSs and 1 non-MS), which represents two additional MSs starting to record a decrease compared with the period 2015–2017. Statistically significant increasing trends in complete susceptibility in indicator *E. coli* from food-producing animals is registered in 11 countries (9 MSs and 2 non-MSs), which represents three additional MSs recording an increase in complete susceptibility compared with the period 2015–2017. These outcome indicators show that some encouraging progress has been registered in reducing AMR in food-producing animals in several EU MSs over the last years.

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1. Introduction

Legal basis

Monitoring of AMR in bacteria from food-producing animals and derived meat

- **Regulation (EC) 178/2002**[1] Article 33 establishes that EFSA is responsible for examining data on AMR collected from the Member States (MSs) in accordance with Directive 2003/99/EC and for preparing the EU Summary Report from the results
- **Directive 2003/99/EC**[2] on the monitoring of zoonoses and zoonotic agents lays down the provisions for monitoring of AMR in zoonotic and indicator bacteria in food-producing animals and derived meat. The Directive obliges EU MSs to collect relevant and, where applicable, comparable data on zoonoses, zoonotic agents, AMR and food-borne outbreaks.
- Implementing **Decision 2013/652/EU**[3] on the monitoring and reporting of antimicrobial resistance in zoonotic and commensal bacteria was adopted as part of the 2011–2016 European Commission action plan. It applies from 2014 to 2020 and sets up priorities for the monitoring of AMR from a public health perspective, drafts a list of combinations of bacterial species, food-producing animal populations and foodstuffs and lays down detailed requirements on the harmonised monitoring and reporting of AMR in food-producing animals and food.

Monitoring of AMR in bacteria from humans

- **Decision 2018/945/EU**[4] on the communicable diseases and related special health issues to be covered by epidemiological surveillance as well as relevant case definitions came into force in July 2018, repealing Decision 2012/506/EU[5]. The new decision stipulates mandatory testing and reporting of a representative subset of isolates using methods and criteria specified in the EU protocol for harmonised monitoring of antimicrobial resistance in human *Salmonella* and *Campylobacter* isolates (ECDC, 2016).
- The data collection on human diseases from MSs is conducted in accordance with **Decision 1082/2013/EU**[6] on serious cross-border threats to health.

Terms of Reference

- In accordance with the Zoonoses **Directive 2003/99/EC,** the EU MSs are required to assess trends and sources of zoonoses, zoonotic agents and AMR, as well as outbreaks in their territory, submitting an annual report each year by the end of May to the European Commission covering the data collected.
- In accordance with Article 9 of **Directive 2003/99/EC**, the EFSA shall examine the submitted national reports of the MSs and publish a summary report on the trends and sources of zoonoses, zoonotic agents and AMR in the EU.
- The ECDC has provided data on zoonotic infections in humans, as well as their analyses, for the EU Summary Reports since 2005. Since 2007, data on human cases have been reported from the European Surveillance System (TESSy), maintained by the ECDC.

[1] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the EFSA and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1–24.

[2] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31–40.

[3] Commission Implementing Decision 2013/652/EU of 12 November 2013 on the monitoring and reporting of antimicrobial resistance in zoonotic and commensal bacteria. OJ L 303, 14.11.2013, p. 26–39.

[4] Commission Implementing Decision 2018/945/EU of 22 June 2018 on the communicable diseases and related special health issues to be covered by epidemiological surveillance as well as relevant case definitions. OJ L 170, 6.7.2018, p. 1–74.

[5] Commission Decision 2012/506/EU amending Decision 2002/253/EC laying down case definitions for reporting communicable diseases to the Community network under Decision No 2119/98/EC of the European Parliament and of the Council. OJ L 262, 27.9.2012, p. 1–57.

[6] Decision No 1082/2013/EU of the European Parliament and of the Council of 22 October 2013 on serious cross-border threats to health and repealing Decision No 2119/98/EC. OJ L 293, 5.11.2013, p. 1–15.

The antimicrobial agents used in food-producing animals and in human medicine in Europe are frequently the same or belong to the same classes. The route of administration and the administered quantities of antimicrobials may differ between humans and food-producing animals and there are important variations between and within food-producing animal populations, as well as between countries. However, the use of antimicrobials in both, humans and animals, might result in the development of AMR, which results from the continuous positive selection of resistant bacterial clones, whether these are pathogenic, commensal or even environmental bacteria. This will change the population structure of microbial communities with serious consequences for human and animal health.

Antimicrobial resistance

AMR is defined as the inability or reduced ability of an antimicrobial agent to inhibit the growth of a bacterium, which, in the case of a pathogenic organism, can lead to therapy failure. A bacterial strain can acquire resistance by mutation, by the uptake of exogenous genes by horizontal transfer from other bacterial strains or by the activation/triggering of a genetic cascade, thereby inducing the expression of resistance mechanisms (EMA and EFSA, 2017). Resistance development can be triggered by different factors such as inappropriate use of antimicrobials in human and veterinary medicine, poor hygiene conditions and practices in healthcare settings or in the food chain facilitating the transmission of resistant microorganisms. Over time, this makes antimicrobials less effective and ultimately useless.

Bacterial resistance to antimicrobials occurring in food-producing animals can spread to humans via food-borne routes, as has been observed for the zoonotic bacteria *Campylobacter*, *Salmonella* and some strains of *Escherichia coli*, by routes such as water or other environmental contamination, as well as through direct animal contact. Infections with antimicrobial resistant bacteria may result in treatment failures or the need of second-line antimicrobials for therapy. The commensal bacterial flora can also form a reservoir of resistance genes, which may be transferred between bacterial species, including organisms capable of causing disease in both humans and animals (EFSA, 2008).

AMR monitoring in zoonotic and commensal bacteria in food-producing animals and their food products entails specific and continuous data collection, analysis and reporting; enables to understand the development and diffusion of resistance, to follow temporal trends in the occurrence and distribution of AMR and the identification of emerging or specific resistance patterns, as well as provides relevant risk assessment data, and evaluates targeted interventions.

This EU Summary Report (EUSR) includes data related to the occurrence of AMR in isolates from animals and foodstuffs and in isolates from human cases, being a collaboration between EFSA and ECDC with the assistance of EFSA's contractors. The EU MSs, the European Commission and the relevant EU Reference Laboratory for antimicrobial resistance (EURL-AR) are consulted, while preparing the report. The efforts made by the MSs and the other reporting countries are gratefully acknowledged.

Data on AMR collected by the EU MSs and compiled in the EUSR on AMR are also used to perform wider analyses, such as the joint report on consumption of antimicrobial agents (AMC) and AMR in animals, food and humans, produced by ECDC, EFSA and EMA, under a One Health approach on a regular basis (JIACRA I and II; ECDC, EFSA and EMA, 2015, 2017). This report provides evidence-based analysis of the possible association between AMC and AMR in humans and food-producing animals. The JIACRA III report should be issued by the Agencies in July 2021.

The current EU action plan against AMR

The European Commission adopted a new Action Plan to tackle AMR on 29 June 2017.[7] The Action Plan is underpinned by a One Health approach that addresses resistance in both humans and animals. The key objectives of this plan are built on three main pillars:

Pillar 1: Making the EU a best practice region: as the evaluation of the 2011 action plan highlighted, this requires better evidence, better coordination and surveillance and better control measures. EU action will focus on key areas and help MSs in establishing, implementing and monitoring their own One Health action plans on AMR, which they agreed to develop at the 2015 World Health Assembly.

[7] https://ec.europa.eu/health/amr/action_eu_en

Pillar 2: Boosting research, development and innovation by closing current knowledge gaps, providing novel solutions and tools to prevent and treat infectious diseases and improving diagnosis in order to control the spread of AMR.
Pillar 3: Intensifying EU effort worldwide to shape the global agenda on AMR and the related risks in an increasingly interconnected world.

In particular, under the first pillar, EU actions will focus on the areas with the highest added value for MSs, e.g. promoting the prudent use of antimicrobials, enhancing cross-sectoral work, improving infection prevention and consolidating surveillance of AMR and antimicrobial consumption. Examples of support include providing evidence-based data with the support of EFSA, EMA and ECDC, updating EU implementing legislation on monitoring and reporting of AMR in zoonotic and commensal bacteria in farm animals and food, to take into account new scientific development and monitoring needs, enabling mutual learning, exchange of innovative ideas and consensus building and co-fund activities in MSs to tackle AMR. The new plan includes more than 75 concrete actions with EU added value that the European Commission will develop and strengthen as appropriate in the coming years. All these important actions are also interdependent and need to be implemented in parallel to achieve the best outcome.

1.1. Monitoring and reporting of antimicrobial resistance in the EU[8]

1.1.1. Monitoring of antimicrobial resistance in animals and food

According to Commission Implementing Decision 2013/652/EU, which applied as of 1 January 2014 until December 2020, monitoring of AMR is mandatory in *Salmonella*, *Campylobacter jejuni* and indicator commensal *E. coli* in the major domestically produced animal populations and their derived meat, corresponding to different production types to collect data that could be combined with those on exposure to antimicrobials. Monitoring is performed on a rotating basis, targeting fattening pigs and bovine animals under 1 year of age and meat derived thereof in odd years and poultry populations and their derived meat in even years, as specified by the legislation. A specific monitoring of extended-spectrum b-lactamase (ESBL)-, AmpC- and carbapenemase-producing *Salmonella* and indicator commensal *E. coli* is also required.

The collection and reporting of data are performed at the isolate level, to enable analyses on the occurrence and traits of multidrug resistance (MDR). Representative random sampling is performed according to the legislation and the technical specifications issued by EFSA in 2014. Monitoring of AMR in food-producing animals is performed in domestically produced animal populations, corresponding to different production types with the aim of collecting data that could be combined with those on exposure to antimicrobials. MSs may also performed complementary monitoring, such as that of MRSA, on a voluntary basis.

Microdilution methods for testing should be used and results should be interpreted by the application of European Committee on Antimicrobial Susceptibility Testing (EUCAST) epidemiological cut-off (ECOFF) values[9] for the interpretation of 'microbiological' resistance. The harmonised panels of antimicrobials used for *Salmonella*, *Campylobacter* and indicator *E. coli* include substances that either are important for human health, such as critically important antimicrobials (CIAs), or can provide clearer insight into the resistance mechanisms involved. The concentration ranges to be used embrace both the ECOFF and the clinical breakpoints (CBPs), as defined by EUCAST, allowing the comparability of results with human data. For *Salmonella* and *E. coli*, a supplementary panel of antimicrobials for testing isolates showing resistance to third-generation cephalosporins or carbapenems in the first panel is also used. MSs may also perform complementary monitoring, such as that of MRSA, on a voluntary basis. The reporting of isolate-based data also allows in-depth phenotypic characterisation of certain mechanisms of resistance, for example, third-generation cephalosporin resistance and carbapenem resistance can be further characterised.

[8] Links to additional information on Materials and methods (Annex A) and supporting data (Annexes B–F) are provided in Appendix H.

[9] The epidemiological cut-off (ECOFF) values separate the naive, susceptible wild-type bacterial populations from isolates that have developed reduced susceptibility to a given antimicrobial agent (Kahlmeter et al., 2003). The ECOFFs may differ from breakpoints used for clinical purposes, which are set out against a background of clinically relevant data, including therapeutic indication, clinical response data, dosing schedules, pharmacokinetics and pharmacodynamics. The use of harmonised methods and ECOFFs ensures the comparability of data over time at the country level and also facilitates the comparison of resistance between MSs.

External quality assurance is provided by the EURL-AR, which distributes panels of well-characterised organisms to all MSs for susceptibility testing, arranges proficiency tests (PTs) trials for the National Reference Laboratories for Antimicrobial Resistance (NRLs-AR) of the MSs on a yearly basis, and, together with EFSA and the MSs, performs a reference testing exercise that includes retesting the antimicrobial susceptibility and whole genome sequencing (WGS) analysis of selected isolates (Annex A, Materials and methods).The EURL-AR also provides a source of reference for MSs when there are issues or problems with the susceptibility test methodology.

1.1.2. Monitoring of antimicrobial resistance in humans

Together with its Food- and Waterborne Diseases and Zoonoses (FWD) network, ECDC has developed an EU protocol for harmonised monitoring of AMR in human *Salmonella* and *Campylobacter* isolates (ECDC, 2014, 2016). This document is intended for the National Public Health Reference Laboratories to guide the susceptibility testing required for EU surveillance and reporting to ECDC. Consultation was also sought from EFSA, EUCAST and the EU Reference Laboratory for antimicrobial resistance to facilitate comparison of data between countries and with results from the AMR monitoring performed in isolates from animals and from food products. The protocol is effective from 2014 and supports the implementation of the Commission Action Plan on AMR. One of the recommendations is that, for the purpose of the joint report with EFSA, human data should also be interpreted based on ECOFFs. As this requires quantitative data, ECDC introduced reporting of quantitative antimicrobial susceptibility testing (AST) results in the 2013 data collection and encourages countries to use it. As the EU protocol is not a legal document in itself, it is for each National Public Health Reference Laboratory to decide whether to adapt their practices to the protocol. Since the entry into force of Decision 2018/945/EU in July 2018; however, laboratories are obliged to report their AMR test results to ECDC according to the methods and criteria specified in the EU protocol. In 2018 and 2019, most laboratories had adopted the priority panel of antimicrobials suggested in the protocol with the exception of the last-line antimicrobials, which were tested by fewer laboratories. The protocol also proposes a testing algorithm for screening and confirmation of ESBL-producing *Salmonella* spp., including detection of AmpC. This has been implemented by some laboratories while others use a modification of the algorithm or test suspected isolates directly with polymerase chain reaction (PCR) or whole genome sequencing. Further testing for ESBL and AmpC was performed in 15 of 20 MSs with third-generation cephalosporin resistance detected in *Salmonella* isolated from humans in 2018, and in 12 of 15 MSs in 2019.

External quality assessment to support laboratories in implementing the recommended test methods and antimicrobials and obtaining high-quality AST results is provided by ECDC via a contract with Statens Serum Institute in Denmark.

1.2. Further harmonised monitoring of antimicrobial resistance

To facilitate the comparability of data, the methodology for AMR surveillance should be harmonised across countries as far as possible. The main issues when comparing AMR data originating from different countries are the use of different laboratory methods and different interpretive criteria of resistance. These issues have been addressed by the development of ECDC's protocol for harmonised monitoring and reporting of resistance in humans and by the legislation on harmonised monitoring in food-producing animals and the food produced.

To respond effectively to the constantly evolving threat of AMR, further enhancements and specific adaptations will be regularly required on an ongoing basis. Under the new One Health action plan (2017), the European Commission is committed to review this legislation, to consider new scientific developments and data collection needs. EFSA received a mandate from the European Commission to provide recommendations on harmonised randomisation procedures for AMR monitoring. The new technical specifications were published in December 2020 (EFSA, 2020) and provide solid scientific advice to support amendments in the existing legislation (see text box below).

New legislation on the monitoring and reporting of AMR in animals and food

Commission Implementing Decision 2013/652/EU lays down rules, for the period 2014–2020, for the monitoring and reporting of antimicrobial resistance (AMR) in zoonotic and commensal bacteria in so far these bacteria present a threat to public health. Monitoring of AMR is essential to have comprehensive and reliable information on the development and spread of resistant bacteria and resistant determinant and as such, AMR data provide insights to inform decision-making and facilitate the development of appropriate strategies and actions to manage AMR at the EU level. In its Communication of 29 June 2017 to the Council and the European Parliament — A European One Health Action Plan against AMR, the Commission committed to review EU implementing legislation, namely Decision 2013/652/EU, on monitoring AMR in zoonotic and commensal bacteria in food-producing animals and food to take into account new scientific developments and data collection needs.

In 2020, based on the new technical specifications issued by EFSA, for implementing updated guidelines for further harmonised monitoring of AMR in food-producing animals and derived meat in the EU and for ensuring continuity in following up further trends in AMR (EFSA, 2019). The European Commission has therefore proposed to lay down new technical requirements for AMR monitoring and reporting that will be applicable as from 1 January 2021 and to repeal, for the sake of clarity, Commission Implementing Decision 2013/652/EU. The new rules are based on the latest scientific opinions but also on the field experience acquired since 2014 by MSs in implementing Decision 2013/652/EU. They address known implementation issues while scientifically responding to the constantly evolving threat of AMR and ensuring continuity in assessing future trends in AMR after 2020. As AMR is a global threat that can easily spread across borders, it is important to improve coordination and gain knowledge to help reducing AMR impact globally. Therefore, the new rules also lay down harmonised AMR monitoring requirements for certain fresh meat imported into the European Union. Commission Implementing Decision 2020/1729 of 17 November 2020 lays down specific technical requirements, for the period 2021–2027, for AMR testing and reporting in representative isolates deriving from randomised sampling in food-producing animals performed at farm and/or at slaughter and derived meat performed at retail and at border control posts.

Technical specifications on randomisation of sampling for monitoring AMR in food-producing animals

EFSA issued new technical specifications in November 2020 for monitoring AMR in zoonotic and indicator bacteria from food-producing animal population and meat thereof, under Decision 2020/1729. This scientific report provides a rationale and harmonised randomisation sampling procedures for AMR monitoring, in samples collected at different stages of the food production chain, yielding representative and comparable data (EFSA, 2020). The current monitoring performed on a biennial basis has been acknowledged as a good compromise between scientific needs and MSs capacities, for the sake of the continuity, the sampling will be performed consistently on a rotating basis. The simple and robust randomised sampling procedure currently in place, relying on a stratified sampling approach with proportional allocation of the sample numbers per strata, is reinforced. A generic proportionate stratified sampling process was proposed for the different sampling plans and numerical illustrations of proportional allocation were also provided. Samples/isolates will be collected according to different selection strategies 'prospective sampling' and 'retrospective sampling'. The former involves collecting enough representative animal and fresh meat samples from which recovered isolates are tested for antimicrobial susceptibility; the latter involves selecting randomly *Salmonella* isolates from collections constituted within the framework of the national control programmes (NCP) of *Salmonella* in poultry flocks. Prospective and retrospective sampling plans for samples and isolates, respectively, were addressed and both collection strategies retained.

Stratified sampling of *Salmonella* isolates from poultry **primary productions** is proposed to be performed with proportional allocation to the size of the isolate collections available in official laboratories. An alternative approach would be a simple random sampling within the sampling frame of flocks positive for *Salmonella*. Regarding *Campylobacter jejuni*, *Campylobacter coli*, indicator *E. coli* and enterococci, stratified sampling of caecal content samples **in the slaughterhouses**, accounting for at least 60% of the national domestic production of the food-producing animal populations monitored, with proportionate allocation to the slaughterhouse production, will allow the collection of representative isolates and the assessment of the prevalence of ESBL-/AmpC-/carbapenemase-producing *E. coli* from the populations of broilers, fattening turkeys, fattening pigs and bovine animals under 1 year of age, domestically produced. Sampling of different chilled fresh meat categories **at retail** outlets serving the final consumer, with proportional allocation of the number of samples to the population of geographical areas accounting for at least 80% of the national population, will allow to test for the presence of ESBL-/AmpC-/carbapenemase-producing *E. coli*. The monitoring of AMR in **imported meat** is introduced in 2021, and the year 2021 will allow to gain experience and knowledge on this topic. As such, the year 2021 should be considered as a transition year regarding this specific part of the harmonised monitoring of AMR. Stratified sampling of different imported fresh meat categories should be performed at border control posts, with

proportional allocation of the number of samples to the number of consignments received per border control post and country of origin, to test *Salmonella* and indicator *E. coli* for antimicrobial susceptibility and to test for the presence of ESBL-/AmpC-/carbapenemase-producing *E. coli.* As the sampling fractions and number of samples to be taken per consignment are indicative, MSs will also have the possibility to adapt them to their own situation, in particular, regarding pig meat and turkey meat.

1.3. The 2018–2019 EU Summary Report on AMR

Most data reported by the MSs comprise data collected in accordance with Commission Implementing Decision 2013/652/EU. The antimicrobial susceptibility data reported to EFSA for 2018 and 2019 for *Campylobacter*, *Salmonella* and indicator *E. coli* isolates from animals and food were analysed and all quantitative data were interpreted using ECOFFs. This report also includes results of phenotypic monitoring of resistance to third-generation cephalosporins and/or carbapenems caused by ESBLs, AmpC b-lactamases or carbapenemases in *Salmonella* and indicator *E. coli*, as well as the investigation at the EU level of the occurrence of complete susceptibility and MDR in data reported at the isolate level. All the information on the methodology applied, list of antimicrobials, criteria, etc. can be found in Annex A 'Materials and methods' available on the EFSA Knowledge Junction community on Zenodo at: https://doi.org/10.5281/zenodo.4557180. Additional information on the data reported in 2018 can also be found in EFSA and ECDC (2020).

The report also includes resistance in *Salmonella* and *Campylobacter* isolates from human cases of salmonellosis and campylobacteriosis, respectively. Results from phenotypic tests were reported by MSs to TESSy either as quantitative or categorical/qualitative data. In addition for 2019, categorical data from whole genome sequencing, where isolates had been categorised as either predicted wild type or predicted non-wild type, corresponding to ECOFFs, were reported to TESSy for the first time. The quantitative phenotypic data were interpreted using EUCAST ECOFFs, where available. The qualitative phenotypic data had been interpreted using CBPs to guide medical treatment of the patient. The breakpoints for 'clinical' resistance are, in many cases, less sensitive than the ECOFF for a specific bacterium–drug combination resulting in higher levels of 'microbiological' resistance than 'clinical' resistance. By combining the categories of 'clinically resistant' (R) and 'susceptible with increased exposure' (I) into one category, however, close correspondence with the ECOFF was achieved. CBPs enable clinicians to choose the appropriate treatment based on information relevant to the individual patient. ECOFFs recognise that epidemiologists need to be aware of small changes in bacterial susceptibility, which may indicate emerging resistance and allow for appropriate control measures to be considered. ECOFFs, CBPs and related concepts on antimicrobial resistance/susceptibility are presented in detail in Annex A 'Materials and methods'.

2. Antimicrobial resistance in *Salmonella* spp.[10]

Monitoring of non-typhoidal salmonellas

Non-typhoidal salmonellas (NTS) are the focus of this section, which summarises the occurrence and AMR patterns of isolates recovered from various food-producing animal populations and their derived carcases. Whereas typhoidal salmonellas are human host-adapted organisms that cause typhoid fever and paratyphoid fever; non-typhoidal strains may be host generalists, infecting or colonising a broad range of animals, or tend to host specificity to particular animal species (Crump et al., 2015). Typhoidal salmonellas refer to *Salmonella enterica* subsp. *enterica* serovars Typhi, Paratyphi A, Paratyphi B (d-tartrate negative) and Paratyphi C, while all other serovars within the subspecies *enterica* (including the d-tartrate positive Paratyphi B variant Java) refer to non-typhoidal salmonellas.

The World Health Organization states that transmission of bacterial infection from non-human sources to humans, with the ability to cause disease, is more evident in particular bacteria (including non-typhoidal *Salmonella*, *Campylobacter* spp. and *E. coli*) and comments that the potential for such transmission should be recognised (WHO, 2019). In 2019, salmonellosis was the second most common zoonosis in the European Union, with 87,923 confirmed human cases, as well as the most frequent cause of food-borne outbreaks accounting for 17.9% of all food-borne outbreaks reported in 2019 (EFSA and ECDC, 2021). A recent review inferred that multidrug-resistant NTS infections may have more serious human health implications compared to those of pan-susceptible strains (Parisi et al., 2018).

[10] Links to additional information on Materials and methods (Annex A) and supporting data for this chapter (Annex B) are provided in Appendix H.

2.1. Data on AMR in *Salmonella* spp. addressed

Commission Implementing Decision 2013/652/EU stipulates detailed protocols for the harmonised monitoring and reporting of antimicrobial resistance (AMR) in zoonotic and commensal bacteria. The monitoring of AMR in *Salmonella* isolates recovered from carcases of broilers and fattening turkeys at slaughter was mandatory in 2018, in accordance with Regulation (EC) No 2073/2005; similarly, the monitoring of AMR in *Salmonella* isolates recovered from carcase swabs of fattening pigs and calves (under 1 year of age) at slaughter was mandatory in 2019. Additionally in 2018, the monitoring of AMR in *Salmonella* isolates recovered from faecal samples and/or environmental samples (boot swabs or dust) of broiler, laying hen and fattening turkey flocks was mandatory, in accordance with Regulation (EC) No 2160/2003, collected as part of National Control Programmes (NCPs) for *Salmonella* in poultry. In 2019, some MSs also reported *Salmonella* AMR data from fattening pigs and calves (under 1 year of age) at slaughter, where in general one representative sample of caecal contents was tested for *Salmonella* per epidemiological unit (i.e. the holding) to prevent clustering. The reporting of such data was not mandatory but was included for completeness.

The *Salmonella* spp. data include results for all serovars reported from the different carcase/animal origins, with one isolate per *Salmonella* serovar from the same epidemiological unit per year being tested for AMR (Decision 2013/652/EU). As the potential for acquiring or occurrence of AMR markedly varies between serovars, the relative contribution of different serovars to the total significantly influences overall resistance levels for *Salmonella* spp. data. Therefore, results have also been presented for selected serovars because of their importance and/or prevalence. Resistance profiles were also considered when less than 10 isolates were recovered from a given carcase/animal origin in a country, to account for the low prevalence of certain serovars, to prevent exclusion of emerging serovars and to ensure that the analysis included all relevant data. (Some graphical figures within this chapter, however, only present individual MS data where 10 or more *Salmonella* spp. were reported, although resistance at the MS group level includes all reported isolates.) The spread of particular resistant clones and the occurrence of resistance genes within these clones can be exacerbated by the use of antimicrobials in human and animal populations and the associated selective pressure. Other factors, such as foreign travel by humans, international food trade, animal movements, farming systems, animal husbandry and the pyramidal structure of some types of animal primary production, may also influence the spread of resistant *Salmonella* clones.

Variations in *Salmonella* prevalence

It is of note that countries reported *Salmonella* spp. data from the different origins according to their national situation. Notably, some MSs did not obtain any positive *Salmonella* isolates from the carcase and animal origins and, therefore, data are not presented for these countries. The number of countries reporting results for pig and broiler carcases was considerably higher than those for calf and turkey carcases, because the size of the veal calf and turkey sectors is relatively small in certain EU MSs, with production levels below the threshold at which mandatory monitoring is required. Additionally, the number of isolates reported by countries varied because of varying *Salmonella* prevalence, and these factors may introduce a source of variation to results when considering all reporting countries.

In both 2018 and 2019, data for *Salmonella* spp. from human cases were also reported. Section 2.2 presents data for 2019, since 2018 data on humans were published in the EU Summary report for 2017/2018 (EFSA and ECDC, 2020). The analysis of AMR in *Salmonella* isolates from human cases includes that of prevalent serovars corresponding to those occurring in animal species.

2.2. Antimicrobial resistance in *Salmonella* from humans

2.2.1. Data reported

For 2019, 24 MSs and two non-MSs reported data on AMR in *Salmonella* isolates from human cases of non-typhoidal salmonellosis. Seventeen countries provided data as measured values (quantitative data), seven as data interpreted with clinical breakpoints and two as predicted phenotypic resistance based on whole genome sequencing. Not all countries reported results for all antimicrobials in the harmonised panel (ECDC, 2016). The reported data represented 26.1% of the confirmed human cases with non-typhoidal *Salmonella* reported in the EU/EEA in 2019.

2.2.2. Occurrence of resistance to commonly used antimicrobials in human and/or veterinary medicine

In 2019, high proportions of human *Salmonella* isolates were resistant to sulfonamides (29.0%), ampicillin (25.8%) and tetracyclines (25.6%) – see Figure 1 and Annex B, Table 1. By serovar, resistance to these compounds ranged from low (4.3–8.0%) in *S.* Enteritidis to extremely high (70.3–87.1%) in monophasic *S.* Typhimurium 1,4,[5],12:i:- and *S.* Kentucky. The variation in the proportion of resistance by country was large. For *S.* Enteritidis, an outlier in terms of high proportion of resistance was observed in Greece for sulfonamides (43.2% – see Annex B, Table 2). For *S.* Infantis, Slovakia reported a much higher resistance (63.2%) to ampicillin than the EU average (18.3%), although the number of isolates tested was low (N = 19), and France reported a much lower proportion of sulfonamide-resistant isolates (10.9% – see Annex B, Table 5). For monophasic *S.* Typhimurium 1,4,[5],12:i:-, two outliers were observed: Malta reported a much lower proportion of ampicillin resistance (64.3%) than other countries and Estonia reported a lower proportion of tetracycline resistance (58.6% – see Annex B, Table 4). Resistance to gentamicin was overall low (2.3% – see Annex B, Table 1), with the exception of *S.* Kentucky where it was high (51.6% – see Annex B, Table 7). Similarly, levels of trimethoprim resistance were overall low among *Salmonella* spp. (7.0% – see Annex B, Table 1), but moderate (14.6–18.6%) in *S.* Kentucky, *S.* Typhimurium and *S.* Infantis (Annex B, Tables 3, 5 and 7).