VETERINARSKI ARHIV 96 (2), 155-163, 2026 DOI: 10.24099/vet.arhiv.2987

Antimicrobial stewardship in pig production: regulatory frameworks and strategic implementation

Zorana Kovačević[1], Miloš Krivokapić[2], Dragana Tomanić[3*] and Snežana Mugoša[2,4]

[1]Department of Veterinary Medicine, Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia
[2]Faculty of Medicine, University of Montenegro, Podgorica, Montenegro
[3]Institute of Food Technology, University of Novi Sad, Novi Sad, Serbia
[4]Institute for Medicine and Medical Devices of Montenegro, Podgorica, Montenegro

KOVAČEVIĆ, Z., M. KRIVOKAPIĆ, D. TOMANIĆ, S. MUGOŠA: Antimicrobial stewardship in pig production: regulatory frameworks and strategic implementation. Vet. arhiv 96, 155-163, 2026.

ABSTRACT

Antimicrobial resistance (AMR) is a critical global health challenge that demands an integrated approach through the establishment and implementation of antimicrobial stewardship (AMS) plans in human and veterinary medicine. This paper reviews the regulatory frameworks, strategic implementation, and practical guidelines for AMS plans in pig farming in order to combat AMR. It highlights key principles such as responsibility, reduction, replacement, refinement, and review, and examines how these principles can be applied to reduce antimicrobial use, prevent AMR, and optimize animal health. Furthermore, the role of international and national regulations is discussed in relation to AMS, including those from the European Union, World Health Organization (WHO), and the Food and Agriculture Organization (FAO). Effective strategies are explored for reducing antimicrobial consumption, improving biosecurity, and promoting alternatives to antimicrobials, such as vaccines and probiotics. The paper emphasizes the need for ongoing monitoring, transparent reporting, and staff education, to ensure the sustainability of AMS efforts in pig production. Ultimately, the integration of AMS into pig farming practices is presented as essential for maintaining the efficacy of antimicrobials and mitigating the risks posed by AMR.

Key words: antimicrobial resistance; antimicrobial stewardship; pig production; antimicrobial use; biosecurity; public health

Introduction

Antimicrobial resistance (AMR) is a global health issue, and it is estimated that by 2050, it could lead to as many as 10 million human deaths annually if sufficient attention is not paid to addressing this problem (O'NEILL, 2016). In addition, bacterial resistance to antibiotics in veterinary medicine can have a significant impact on animal health, public health, and food safety (JANS et al., 2018). Moreover, AMR not only poses a threat to human and animal health, but also contributes to economic losses. According to data from the World Bank, unsuccessful therapy leads to increased veterinary costs and reduced animal productivity,

* Corresponding author:
Dragana Tomanić, Research Associate, Institute of Food Technology, University of Novi Sad, Bulevar Cara Lazara 1, 21000 Novi Sad, Serbia, phone: +381 21 485-3812, e-mail: dragana.tomanic@fins.uns.ac.rs

ISSN 0372-5480
Printed in Croatia

which may have far-reaching negative consequences for farms and the global economy as a whole (WORLD BANK GROUP, 2024). For this reason, the use of antimicrobials on pig farms must comply with strict regulatory requirements and best practices in order to protect animal health, reduce the risk of AMR emergence and spread, and ensure product safety. One of the current effective strategies to combat AMR is the development and implementation of antimicrobial stewardship (AMS) programs aimed at optimizing antibiotic use in both human and veterinary medicine (JAYARAO et al., 2019).

AMS is a strategy that was developed in 2007 with the aim of achieving better clinical outcomes in the treatment of infections through the careful selection of antimicrobials, as well as appropriate administration routes, dosing, and duration of therapy (DELLIT et al., 2007). In the context of veterinary medicine, this term implies the multifaceted and dynamic approaches necessary to preserve the clinical efficacy of antimicrobials through their optimal use. Optimal use involves the careful selection of the appropriate antimicrobials, including dose, duration of therapy, and route of administration, while minimizing the risk of AMR development and adverse effects. The term "stewardship" conveys a broader sense of responsibility for preserving critically important resources for future generations, having a far-reaching impact that goes beyond terms such as "judicious" or "rational use" (GUARDABASSI and PRESCOTT, 2015; LLOYD and PAGE, 2018). This concept is essential in veterinary medicine, where AMS constitutes an integral part of responsible use of antimicrobials.

The purpose and objectives of antimicrobial stewardship plans in pig production

AMS is a concept that is still evolving but is founded on five key principles known as the "5 R": Responsibility, Reduction, Replacement, Refinement, and Review (PRESCOTT, 2019). A broader framework is provided by the Good Stewardship Practice (GSP) 5R model, which, in addition to these five principles, includes the notion of GSP. This model emphasizes a structured and proactive approach to the responsible use of antimicrobials in veterinary medicine. Responsibility involves the engagement of all stakeholders in the proper use of antimicrobials, including veterinarians, animal owners, and producers. Reduction refers to the need to minimize the use of antimicrobials through effective disease prevention strategies, improved animal husbandry, and the implementation of nutritional and biosecurity measures. Replacement encourages the use of alternative methods whenever possible, such as vaccination and natural additives in the form of organic acids, probiotics, prebiotics, synbiotics, and phytobiotics. Refinement focuses on optimizing the use of antimicrobials by ensuring the selection of the most appropriate drug, correct dosing, adequate duration of therapy, and proper route of administration. Finally, Review entails continuous monitoring and assessment of antimicrobial usage to ensure effectiveness and safety, and to reduce the risk of AMR development and dissemination (LLOYD and PAGE, 2018).

The purpose of developing and implementing an AMS plan on pig farms is strategically to reduce the overall use of antimicrobials in pig production while simultaneously applying preventive measures. This plan aims to prevent and control the spread of AMR through consistent application of the principles of responsible antimicrobial use. Through staff education and training, AMS plans must ensure that all participants in the production process are equipped to apply the best practices, thereby contributing to sustainable production and preserving the efficacy of antimicrobials in veterinary medicine. Beside, AMS plans should be based on the recommendations from international organizations such as the World Health Organization (WHO), the World Organisation for Animal Health (WOAH), and the Food and Agriculture Organization of the United Nations (FAO). Furthermore, AMS plans should also incorporate the European Union (EU) guidelines on the prudent use of antimicrobials, particularly those issued by the European Medicines Agency (EMA) (EMA, 2019). In addition, the AMS plan must thoroughly comply with national legislation in the countries where it has to be implemented.

The primary objectives of AMS plans in pig production include: (1) reduction of antimicrobial use, (2) prevention of AMR, (3) improvement of animal health and reduction of antimicrobial need, (4) controlled antimicrobial application, (5) alignment with legal frameworks and international recommendations, (6) transparency and reporting, and (7) staff training and education.

A key focus of AMS plans is to minimize the overall use of antimicrobials (1), particularly those considered critically important for human health. Special attention is given to antimicrobials classified under Category B ("Restrict") by the Antimicrobial Expert Group (AMEG) of the EMA, as these pose a higher risk for development of resistance relevant to public health (EMA, 2019). The EMA categorization — adopted from the WHO list of critically important antimicrobials (CIAs) — divides drugs into four categories: Category A ("Avoid"): Not authorized for use in food-producing animals; use limited to companion animals under exceptional conditions. Category B ("Restrict"): Critically important for human medicine; should only be used in animals when no alternatives from Categories C or D are effective. Category C ("Caution"): Alternatives exist in human medicine; used in animals only when no suitable drugs from Category D are available. Category D ("Prudence"): First-line options for veterinary use; should be used responsibly and only when medically justified (EMA, 2019). This categorization assists veterinarians in choosing appropriate antimicrobials while considering drug characteristics, species-specific restrictions, and summary of product characteristics (SmPCs). Antimicrobial policies in pig production emphasize avoiding Category B antimicrobials unless strictly necessary, favoring diagnostics-based, justified treatments. Continuous monitoring and reporting of antimicrobial use are crucial to ensure appropriate stewardship and to reduce the emergence of resistant bacterial strains.

When it comes to the prevention and development of AMR (2), implementing strategies that reduce the emergence and spread of resistant bacterial strains on pig farms contributes to preserving the effectiveness of antimicrobials for future generations. Studies conducted in several EU countries have shown a reduction in overall antimicrobial use through the implementation of appropriate biosecurity measures and health management practices on pig farms (LAANEN et al., 2014; POSTMA et al., 2016; STYGAR et al., 2020). An intervention study in Belgium demonstrated that improving farm management and the status of biosecurity measures, combined with antimicrobial use management, helped reduce antimicrobial use in pigs from birth to slaughter by 52%, and in sows by 32% (POSTMA et al., 2017). This strategy, which included farmer education and interventions aimed at improving management and biosecurity, was relatively simple and achieved a high implementation rate among farmers. For example, farmers' work habits and routines were revised (e.g., needle changes, personal hygiene, and water quality analysis). More expensive interventions, such as installing a new hygiene system for changing clothes/boots and hand-washing facilities were less frequently implemented.

An important objective of AMS plans, improving animal health and reducing the need for antimicrobials (3), involves enhancing health practices, biosecurity measures, and vaccination programs to reduce disease occurrence and the need for antimicrobial use. Focusing on biosecurity measures on farms, several studies have demonstrated that improvements in biosecurity lead to reduced antimicrobial use, while maintaining similar levels of livestock production performance. A study conducted on pig farms in France, from farm to slaughterhouse, showed that farms with lower antimicrobial use were associated with implementation of key biosecurity measures (e.g., disinfection at loading areas) (LAANEN et al., 2014). The Biocheck. UGent® system for assessing biosecurity status has been used in numerous studies, as it allows researchers to include measurable data on biosecurity practices, and directly link them to data on antimicrobial use. In Belgium, it was found that pig farms with higher internal biosecurity scores from farm to slaughterhouse used antimicrobials for fewer days per production batch, indicating lower antimicrobial consumption (LAANEN et al., 2014). Similar results were observed in Germany, where lower external biosecurity scores were associated with

higher antimicrobial use (RAASCH et al., 2018). A study in Finland reported that higher and improved levels of external biosecurity on large farms were correlated with lower antimicrobial use, while farms with low biosecurity scores — particularly in internal subcategories — had higher percentages of resistant isolates (YUN et al., 2021).

Beside these objectives, controlled use of antimicrobials (4) includes the use of these drugs only when necessary and strictly under veterinary supervision, in accordance with legal regulations and guidelines on prudent, wise, and responsible use, while harmonizing farm activities with legal regulations and recommendations (5) ensures that all farm activities comply with national and international legislation, including EU regulations and recommendations from the FAO, WOAH, WHO, and EMA. Furthermore, transparency and reporting on antimicrobial use (6) is related to establishing systems for monitoring, recording, and reporting antimicrobial use both within the farm and to the relevant authorities, in order to ensure transparency and accountability in the use of these drugs on pig farms, while training and education of pig farm employees (7) includes continuous training and education of pig farm employees on the proper handling, administration, and disposal of antimicrobials, the mechanisms and spread of AMR, risks associated with AMR, and the importance of disease prevention through appropriate practices.

Regulatory framework

The use of antimicrobials in livestock production across the EU is governed by a comprehensive legislative framework aimed at reducing AMR and safeguarding both public and animal health. This regulatory architecture ensures the responsible and controlled use of antimicrobials in pig farming, with a strong emphasis on preserving the efficacy of existing antimicrobials and preventing the emergence and spread of resistant bacteria.

A cornerstone of EU veterinary legislation is Regulation (EU) 2019/6 on veterinary medicinal products (EUR-Lex, 2019b). This regulation stipulates that antimicrobials may only be administered upon veterinary prescription and strictly according to the conditions outlined in the SmPCs. Prophylactic and metaphylactic use of antimicrobials in group treatments is heavily restricted. Prophylactic use is permitted only in exceptional cases involving individual animals or a limited number of animals at high risk of infection, while metaphylactic use is allowed solely when the spread of infectious disease within a group is imminent and no viable alternatives exist (EUR-Lex, 2019b). In parallel, Regulation (EU) 2019/4 on medicated feed further reinforces the principles of prudent antimicrobial use (EUR-Lex, 2019a). It prohibits the manufacture and use of medicated feed for mass antimicrobial administration without veterinary oversight, particularly in prophylactic contexts. The regulation emphasizes that disease prevention must rely primarily on good animal husbandry practices, biosecurity, and proper farm management, rather than routine antimicrobial treatment. Metaphylactic use of medicated feed is allowed only under specific conditions of elevated infection risk (EUR-Lex, 2019a). The EU has also adopted a comprehensive One Health Action Plan against AMR, targeting human, veterinary, and environmental sectors (EC, 2017). Within this plan, reducing antimicrobial usage in animal husbandry — especially in pig farming — is a major objective, supported by the promotion of alternatives such as vaccination, enhanced biosecurity, and probiotics. As mentioned above, the EMA, together with its AMEG, has developed guidelines for the responsible use of antimicrobials in animals. These include a risk-based classification system that restricts the use of certain CIAs, such as third- and fourth-generation cephalosporins, fluoroquinolones, polymyxins, and glycopeptides, in food-producing animals (EMA, 2020). Food safety and animal health legislation, such as Regulation (EU) 2020/687 and Regulation (EC) No 178/2002, provide the foundational principles for ensuring that the use of veterinary drugs does not compromise food safety for consumers (EUR-Lex, 2002; EUR-Lex, 2020). Member States are required to monitor and manage residues and ensure compliance with safety standards. In addition to EU-wide measures, each Member State is obligated to implement national action plans to reduce antimicrobial usage in livestock. These plans are

aligned with EU objectives, and tailored to national priorities and production systems, aiming to mitigate AMR risks through surveillance, education, and targeted interventions (3).

Globally, similar efforts are coordinated by the FAO and the WHO. The FAO's Action Plan on AMR (2016–2020) provides strategic guidance to Member States for developing national policies (FAO, 2016). The FAO advocates limiting prophylactic use, banning antimicrobial growth promoters, and implementing Good Agricultural Practices (GAP), including hygiene and biosecurity measures. It also encourages the development of national AMR strategies (FAO, 2016). The WHO's Global Action Plan on AMR, developed in collaboration with the FAO and WOAH, promotes veterinary oversight for all antimicrobial use, the prohibition of CIAs in animal production, and the establishment of surveillance systems for antimicrobial use and resistance (WHO, 2015). It also urges countries to invest in alternatives to antimicrobials, such as vaccines, probiotics, and phytogenic products (WHO, 2015). Collectively, these international and regional frameworks provide a cohesive foundation for AMS in pig production, balancing the need for animal health interventions with the overarching goal of protecting human and environmental health.

Standards for monitoring and reporting antimicrobial use

Antimicrobial use on pig farms has become one of the most scrutinized aspects of livestock production within the EU's efforts to combat AMR. With growing concern over the loss of antimicrobial efficacy, the EU has set ambitious goals to regulate veterinary antimicrobial use, especially in intensive production systems such as pig farming. A cornerstone of this approach is the implementation of standardized and mandatory antimicrobial usage reporting systems, enabling consistent and transparent data collection across member states (EMA, 2022; ESVAC 2023; EUR-Lex, 2021).

Pig farms are now required to systematically record detailed information on antimicrobial use, including the type of product (categorized according to the ATCvet classification), quantity administered, route of administration (individual treatment, group medication, or prophylaxis), and duration of treatment. These data must be made available to the competent national authorities, which in turn report them to the EMA for centralized monitoring and trend analysis (EUR-Lex, 2019b; EUR-Lex, 2021; EMA, 2023). A particularly important regulatory change took effect from 2024, when all EU member states had to begin collecting animal species-specific data on antimicrobial usage. Initially, this includes cattle, pigs, chickens, and turkeys, with other species — such as sheep, goats, fish, rabbits, and horses — to be added by 2027. By 2030, data collection will also encompass pets and fur animals (EUR-Lex, 2021).

This comprehensive data gathering serves several purposes. Most notably, it identifies areas and species where antimicrobial use is high, or where CIAs for human medicine are still in use. It also enables environmental risk assessment related to antimicrobial residues in manure and runoff, informing strategies for waste management. Additionally, it supports monitoring of off-label use of veterinary medicinal products, highlighting gaps in approved indications or dosing regimens (EMA, 2018a).

To ensure comparability, usage data are analyzed using a standardized denominator—the Population Correction Unit (PCU). The PCU represents the estimated animal biomass exposed to treatment within a country or production system, calculated by multiplying the number of animals in a category by a standard weight at treatment. This allows benchmarking across species and countries, and supports targeted interventions (EMA, 2023;EMA, 2018b).

The legal basis for these activities is Regulation (EU) 2019/6 on veterinary medicinal products, which strictly prohibits the routine prophylactic use of antimicrobials in groups of animals, except in exceptional cases. The regulation emphasizes the importance of targeted therapeutic use, and encourages the adoption of non-antimicrobial alternatives through improved biosecurity, vaccination, and optimized animal welfare practices (EUR-Lex, 2019b).

Education plays a pivotal role in achieving these goals. Farmers and veterinarians must be trained in the principles of prudent antimicrobial use, and informed about the risks associated with misuse, including AMR development. Education has been recognized as one of the most effective tools to improve compliance and promote sustainable AMS in livestock farming (EFSA and ECDC, 2022). Equally important is the role of regulatory inspections and on-site audits. National authorities conduct regular checks to ensure that farms comply with the reporting requirements and antimicrobial use regulations. When irregularities are detected, corrective measures may include administrative sanctions or suspension of farm operations (EMA, 2023). This oversight ensures data reliability and reinforces accountability.

One important aspect is the avoidance of CIAs for human medicine in veterinary practice to reduce the development of AMR, primarily because they are critical and often save human lives (WHO, 2018). Some countries have completely banned the use of CIAs in pigs and/or poultry, while in other countries, their prescription is allowed only after conducting a sensitivity test that shows these antimicrobials are the only therapeutic option for treatment. Other categories of CIAs are those that are of critical importance to veterinary medicine (OIE, 2019). Therefore, recommendations for their use in animals must take animal health into account. The overlap between these lists requires careful consideration in order to adequately balance the needs for animal health and public health aspects.

Ultimately, these efforts form part of the EU's broader AMR strategy, which relies on coordinated action between the regulatory bodies, farmers, veterinarians, researchers, and international organizations. Only through such collective action can the effectiveness of antimicrobials be preserved for future generations, safeguarding both animal and public health.

Antimicrobial stewardship plan implementation on pig farms: a structured and farm-specific approach for practical implementation

The AMS plan for pig farms is based on the establishment of general objectives and their implementation through clearly defined stages. It is essential that the plan has to be practical, tailored to the specific conditions of each farm, and aligned with both EU and national veterinary antimicrobial use regulations. The preliminary steps for implementing the AMS plan include: defining the implementation stages with clearly set timelines, designating responsible personnel at both the company and farm levels, and clarifying farm obligations in applying and supervising all phases of the plan.

Each farm must ensure consistent implementation of the defined measures, maintain detailed and accurate records of antimicrobial use (ideally using digital systems), submit regular quarterly or annual reports, monitor total usage by antimicrobial class and per animal species, and ensure ongoing education of staff on appropriate antimicrobial use, AMR risks, and disease prevention strategies. Additionally, farms are obligated to implement preventive and biosecurity measures, such as adequate housing, vaccination, proper nutrition, and effective population management, to reduce the need for antimicrobials. Effective communication must be established with the company-level implementation manager, who oversees coordination, progress reporting, and the proposal of improvements. Furthermore, farms must regularly report on the implementation of measures and outcomes, to support evaluation and continuous improvement.

The implementation of the AMS plan involves a structured process through several key phases. The first phase is information gathering and analysis of the current situation, which includes on-site inspection of farm conditions, data collection on treatment protocols, prophylactic use, disease frequency and treatment success, and identification of critical areas of concern. The second phase involves developing precise antimicrobial use protocols based on diagnosis, respecting antimicrobial categorization (especially differentiating those critical for human medicine as per AMEG classification), defining appropriate dosages and durations of treatment, and ensuring comprehensive documentation of all antimicrobial use, including the prescriber, the reason, dose, and the treatment period. The third phase focuses on preventive measures, such as expanding vaccination programs, enhancing biosecurity to

prevent disease entry and spread (e.g., access restrictions, disinfection, quarantine), and improving hygiene and animal nutrition, while the fourth phase is dedicated to monitoring and evaluating the implementation of the AMS plan, including the establishment of systems for regular monitoring of antimicrobial use and health indicators, assessment of effectiveness, and preparation of reports to guide decision-making. The fifth phase ensures the creation of clear documentation and regular revision of the AMS plan in accordance with legislative updates, scientific developments, and farm-specific needs. The sixth phase emphasizes communication with veterinary services and competent authorities to ensure regulatory compliance and transparency, especially when reporting diseases that require antimicrobial treatment. Finally, the seventh phase entails continuous staff training and education, which includes both internal lectures and participation in external seminars and conferences, with regular assessment of knowledge and maintenance of training records.

This comprehensive and systematic approach allows for the gradual implementation of stewardship measures, facilitates continuous improvement, and contributes to responsible antimicrobial use, reducing the risk of AMR and improving animal health on pig farms.

Conclusions

The implementation of AMS plans in pig production is a critical step in mitigating the rising threat of AMR. By adhering to strict regulatory frameworks, pig farms can significantly reduce the use of antimicrobials and improve animal health, while preventing the emergence and spread of resistant bacteria. The key principles of AMS, including responsibility, reduction, replacement, refinement, and review, should guide the development and execution of effective strategies to optimize antimicrobial use in veterinary medicine. Practical measures, such as enhancing biosecurity, incorporating alternative methods such as vaccines and probiotics, and improving farm management practices, are crucial to achieving the objectives of AMS. Additionally, monitoring and reporting antimicrobial use on pig farms must be standardized to ensure transparency and accountability. Education and training for all stakeholders involved in pig farming will further support the successful implementation of AMS and contribute to its long-term sustainability. In conclusion, the development of a comprehensive AMS plan tailored to pig production is not only aligned with international health priorities, but also serves to protect both animal and human health. By balancing the need for antimicrobials with responsible use practices, we can safeguard the efficacy of these critical resources for future generations, ultimately contributing to the global efforts to combat AMR.

Financial support statement

This study was supported by the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia [Grant Number 451-03-137/2025-03/200117 and Grant Number 451-03-136/2025-03/200222].

Declaration of competing interest

The authors declare no conflict of interest.

References

DELLIT, T. H., R. C. OWENS, J. E. MCGOWAN, D. N. GERDING, R. A. WEINSTEIN, J. P. BURKE, W. C. HUSKINS, D. L. PATERSON, N. O. FISHMAN, C. F. CARPENTER, P. J. BRENNAN, M. BILLETER, T. M. HOOTON (2007): Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin. Infect. Dis. 44, 159-177.

https://doi.org/10.1086/510393

EC (2017): European Commission. A European One Health Action Plan against Antimicrobial Resistance (AMR). Brussels: European Commission. Available from: https://health.ec.europa.eu/system/files/2020-01/amr_2017_action-plan_0.pdf

EFSA and ECDC (2022): European Food Safety Authority and European Centre for Disease Prevention and Control. The European Union Summary Report on Antimicrobial Resistance in zoonotic and indicator bacteria from humans, animals and food in 2020/2021. EFSA Journal 20, e07209.

https://doi.org/10.2903/j.efsa.2022.7209

EMA (2022): European Medicines Agency. Sales of veterinary antimicrobial agents in 31 European countries in 2021: Trends from 2012 to 2021. Available from: https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-31-european-countries-2021-trends-2010-2021-twelfth-esvac-report_en.pdf

EMA (2020): European Medicines Agency. Categorisation of antibiotics in the EU – AMEG categorisation. Available from: https://www.ema.europa.eu/en/documents/report/infographic-categorisation-antibiotics-use-animals-prudent-and-responsible-use_en.pdf

EMA (2019): European Medicines Agency. Categorisation of antibiotics in the European Union. Answer to the request from the European Commission for updating the scientific advice on the impact on public health and animal health of the use of antibiotics in animals. EMA/CVMP/CHMP/682198/2017. Available from: https://www.ema.europa.eu/system/files/documents/report/ameg_-_categorisation_of_antibiotics_en.pdf

EMA (2018a): European Medicines Agency. Antimicrobial resistance: Impact on human and animal health and the environment. Available from: https://www.ema.europa.eu/en/human-regulatory-overview/public-health-threats/antimicrobial-resistance

EMA (2018b): European Medicines Agency. Guidance on collection and provision of national data on antimicrobial use by animal species/categories. Available from: https://www.ema.europa.eu/en/documents/scientific-guideline/guidance-collection-and-provision-national-data-antimicrobial-use-animal-speciescategories_en.pdf

ESVAC (2023) European Surveillance of Veterinary Antimicrobial Consumption report. Available from: https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-31-european-countries-2021-trends-2012-2021-eleventh_en.pdf

EUR-Lex (2021): Regulation (EU) 2021/578 of 8 April 2021 on the collection of data on the volume of sales and on the use of antimicrobial medicinal products in animals. Official Journal of the European Union L 124, 1-10.

EUR-Lex (2020): Regulation (EU) 2020/687 of the European Parliament and of the Council on protective measures against animal diseases. Official Journal of the European Union. L174, 64-125.

EUR-Lex (2019a): Regulation (EU) 2019/4 of the European Parliament and of the Council of 11 December 2018 on the manufacture, placing on the market and use of medicated feed. Official Journal of the European Union L4, 1-23.

EUR-Lex (2019b): Regulation (EU) 2019/6 of the European Parliament and of the Council of 11 December 2018 on veterinary medicinal products and repealing Directive 2001/82/EC. Official Journal of the European Union L4, 43-167.

EUR-Lex (2002): Regulation (EC) No 178/2002 of the European Parliament and of the Council laying down the general principles and requirements of food law. Official Journal of the European Communities L31, 1-24.

FAO (2016): Food and Agriculture Organization of the United Nations. The FAO Action Plan on Antimicrobial Resistance 2016-2020. Supporting the food and agriculture sectors in implementing the Global Action Plan on Antimicrobial Resistance to minimize the impact of antimicrobial resistance. FAO, Rome.

GUARDABASSI, L., J. F. PRESCOTT (2015): Antimicrobial stewardship in small animal veterinary practice: from theory to practice. Vet. Clin. North Am. Small Anim. Pract. 45**,** 361-376.
https://doi.org/10.1016/j.cvsm.2014.11.005

JANS, C., E. SARNO, L. COLLINEAU, L. MEILE, K. D. STÄRK, R. STEPHAN (2018): Consumer exposure to antimicrobial resistant bacteria from food at Swiss retail level. Front. Microbiol. 9**,** 362.
https://doi.org/10.3389/fmicb.2018.00362

JAYARAO, B., R. ALMEIDA, S. P. OLIVER (2019): Antimicrobial resistance on dairy farms. Foodborne Pathog. Dis. 16, 1-4.
https://doi.org/10.1089/fpd.2019.29011.edi

LAANEN, M., D. MAES, C. HENDRIKSEN, P. GELAUDE, S. DE VLIEGHER, Y. ROSSEEL, J. DEWULF (2014): Pig, cattle and poultry farmers with a known interest in research have comparable perspectives on disease prevention and on-farm biosecurity. Prev. Vet. Med. 115, 1-9.
https://doi.org/10.1016/j.prevetmed.2014.03.015

LLOYD, D. H., S. W. PAGE (2018): Antimicrobial stewardship in veterinary medicine. Microbiol. Spectr. 6, 22.
https://doi.org/10.1128/microbiolspec.ARBA-0023-2017

OIE (2019): World Organisation for Animal Health. Critically important antimicrobial agents for veterinary medicine. Available from https://www.oie.int

O'NEILL, J. (2016): Tackling drug-resistant infections globally: final report and recommendations. Review on Antimicrobial Resistance. Avaiable from: https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf

POSTMA, M., W. VANDERHAEGHEN, S. SARRAZIN, D. MAES, J DEWULF (2017): Reducing antimicrobial usage in pig production without jeopardizing production parameters. Zoonoses Public Health 64, 63-74.
https://doi.org/10.1111/zph.12283

POSTMA, M., D. SPEKSNIJDER, A. JAARSMA, TJ VERHEIJ, J. WAGENAAR, J. DEWULF (2016): Opinions of veterinarians on antimicrobial use in farm animals in Flanders and the Netherlands. Vet. Rec. 179, 68-68.
https://doi.org/10.1136/vr.103618

PRESCOTT, J. F. (2019): Veterinary antimicrobial stewardship in North America. Aust. Vet. J. 97**,** 243-248.
https://doi.org/10.1111/avj.12811

RAASCH, S., M. POSTMA, J. DEWULF, K. STÄRK, E. GROSSE BEILAGE (2018): Association between antimicrobial usage, biosecurity measures as well as farm performance in German farrow-to-finish farms. Porc. Health Manag. 4, 30. https://doi.org/10.1186/s40813-018-0106-5

STYGAR, A., I. CHANTZIARAS, I. TOPPARI, D. MAES, J. NIEMI (2020): High biosecurity and welfare standards in fattening pig farms are associated with reduced antimicrobial use. Animal 14, 2178-2186. https://doi.org/10.1017/S1751731120000828

WHO (2018): World Health Organization. Critically important antimicrobial agents for human medicine. Available from: https://www.who.int

WHO (2015): World Health Organization. Global Action Plan on Antimicrobial Resistance. Geneva. Available from: https://www.who.int/publications/i/item/9789241509763

WORLD BANK GROUP (2024): Addressing the Grand Pandemic of Antimicrobial Resistance. Available from :https://thedocs.worldbank.org/en/doc/383d4b187ee458d9d9f-9 b593644641a 40140022024/ related/ Addressing-grand-pandemic-antimicrobial-resistance-3-pager.pdf

YUN, J., J. MUURINEN, S. NYKÄSENOJA, L. SEPPÄ-LASSILA, V. SALI, J. SUOMI, P. TUOMINEN, S. JOUTSEN, M. HÄMÄLÄINEN, S. OLKKOLA, A.-L. MYLLYNIEMI, O. PELTONIEMI, M. HEINONEN (2021): Antimicrobial use, biosecurity, herd characteristics, and antimicrobial resistance in indicator *Escherichia coli* in ten Finnish pig farms. Prev. Vet. Med. 193, 105408. https://doi.org/10.1016/j.prevetmed.2021.105408

Received: 9 May 2025
Accepted: 13 May 2025
Online publication: 10 October 2025

KOVAČEVIĆ, Z., M. KRIVOKAPIĆ, D. TOMANIĆ, S. MUGOŠA: Upravljanje upotrebom antimikrobnih lijekova u u proizvodnji svinja: regulativni okviri i strateška implementacija. Vet. arhiv 96, 155-163, 2026.

SAŽETAK

Antimikrobna rezistencija (AMR) ozbiljan je globalni zdravstveni izazov koji zahtijeva integrirani pristup putem uspostave i provedbe planova za odgovornu primjenu antimikrobnih sredstava (AMS) u humanoj i veterinarskoj medicini. Ovaj rad daje pregled regulativnih okvira, strateške provedbe i praktičnih smjernica za AMS planove u uzgoju svinja s ciljem suzbijanja AMR-a. Ističu se ključna načela kao što su odgovornost, smanjenje, zamjena, poboljšanje i revizija, te se analizira kako se ta načela mogu primijeniti za smanjenje upotrebe antimikrobnih sredstava, prevenciju AMR-a i optimizaciju zdravlja životinja. Također, u kontekstu AMS-a, se raspravlja o ulozi međunarodnih i nacionalnih propisa, uključujući one Europske unije, Svjetske zdravstvene organizacije (WHO) i Organizacije za hranu i poljoprivredu (FAO). Istražuju se učinkovite strategije za smanjenje potrošnje antimikrobnih sredstava, poboljšanje biosigurnosti i promicanje alternativa antimikrobicima, kao što su cjepiva i probiotici. Rad naglašava potrebu za stalnim praćenjem, transparentnim izvještavanjem i edukacijom osoblja kako bi se osigurala održivost AMS napora u proizvodnji svinja. Konačno, integracija AMS-a u praksu u uzgoju svinja prikazana je kao ključna za očuvanje učinkovitosti antimikrobnih sredstava i smanjenje rizika koje AMR predstavlja.

Ključne riječi: antimikrobna rezistencija; odgovorna primjena antimikrobnih lijekova; uzgoj svinja; biosigurnost; javno zdravlje