Open Access Article

Ann. Acad. Med. Siles. (online) 2025; 1(nr specj.): 83–92
eISSN 1734-025X
DOI: 10.18794/aams/209990
www.annales.sum.edu.pl

PRACA POGLĄDOWA
REVIEW

The presence of antibiotics in food and the consequences for human health

Obecność antybiotyków w żywności i jej konsekwencje dla zdrowia człowieka

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ABSTRACT

Modern technological advancements are intensifying activities across numerous sectors, including human medicine, veterinary medicine, and agriculture. These fields are closely interconnected, notably through the widespread use of antibiotics. These antimicrobial agents, employed in the treatment of both humans and animals, are increasingly associated with significant public health and environmental concerns. The excessive and unregulated use of antibiotics in livestock production, combined with the application of manure and other animal-derived products as agricultural fertilizers, contributes to the accumulation of these substances in the environment and their subsequent entry into the food chain. Consequently, antibiotic residues may be detected in food products. Prolonged exposure to subtherapeutic doses of antibiotics can promote the development of bacterial resistance (antimicrobial resistance), as well as induce various adverse health effects, including hepatotoxicity, allergic reactions, and potential carcinogenicity. In light of these risks, the establishment of maximum residue limits (MRLs) and the implementation of guidelines for the prudent use of antibiotics in animal husbandry and agriculture are essential for safeguarding public health. The presence of antibiotic residues in food represents a significant threat to public health, primarily due to its role in accelerating antimicrobial resistance. Therefore, the judicious use of these substances in agriculture and livestock farming, supported by robust regulatory frameworks and effective sanitary monitoring throughout the food production chain, is of paramount importance.

KEYWORDS

antibiotics, antimicrobial resistance, environmental contamination, food safety, veterinary medicine

Received: 25.07.2025 **Revised:** 25.08.2025 **Accepted:** 27.08.2025 **Published online:** 22.12.2025

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STRESZCZENIE

Współczesny rozwój technologiczny przyczynia się do intensyfikacji działań w wielu dziedzinach, w tym w medycynie, weterynarii i rolnictwie. Obszary te są ze sobą ściśle powiązane, m.in. poprzez powszechne zastosowanie antybiotyków. Preparaty te (substancje bakteriobójcze), wykorzystywane zarówno w leczeniu ludzi, jak i zwierząt, coraz częściej stanowią źródło problemów zdrowotnych i środowiskowych. Nadmierne i niekontrolowane stosowanie antybiotyków w hodowli, a także nawożenie pól uprawnych obornikiem i innymi produktami pochodzenia zwierzęcego, prowadzi do ich akumulacji w środowisku i przenikania do łańcucha pokarmowego. W konsekwencji w żywności mogą występować pozostałości substancji przeciwdrobnoustrojowych. Długotrwała ekspozycja na niskie dawki antybiotyków może skutkować rozwojem oporności bakterii na leczenie (antybiotykooporność), a także wywoływać inne działania niepożądane, takie jak hepatotoksyczność, reakcje alergiczne czy potencjalne działanie rakotwórcze. Z tego względu kluczowe znaczenie mają regulacje prawne określające dopuszczalne poziomy pozostałości (*maximum residue limits* – MRLs) oraz zasady racjonalnego stosowania antybiotyków w produkcji zwierzęcej i rolniczej, których celem jest ochrona zdrowia publicznego. Obecność antybiotyków w żywności stanowi istotne zagrożenie dla zdrowia publicznego, głównie poprzez nasilenie zjawiska antybiotykooporności. Dlatego kluczowe znaczenie ma racjonalne stosowanie tych substancji w hodowli i rolnictwie, a także skuteczna kontrola legislacyjna i sanitarna na wszystkich etapach produkcji żywności.

SŁOWA KLUCZOWE

antybiotyki, antybiotykooporność, zanieczyszczenie środowiska, bezpieczeństwo żywności, medycyna weterynaryjna

INTRODUCTION

Antibiotics are a group of critically important drugs for both humans and animals, as demonstrated by their widespread use in various sectors such as agriculture, aquaculture, human medicine, animal nutrition, and livestock farming [1]. They are defined as substances capable of killing or inhibiting the growth of bacteria [2]. Veterinary medicines – antibiotics among them – play a key role in animal health and feed production and in maintaining the health of livestock, with estimates indicating that in 2015, approximately 80% of food-producing animals underwent veterinary treatment at various stages of their lives, and sometimes throughout their entire rearing period [2]. Over a 12-year period, the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project led to a reduction of more than 50% in the sales of veterinary antibiotics in Europe, demonstrating that effective animal treatment can be achieved while substantially limiting antibiotic use [3].

Globally, the consumption of these agents by livestock is estimated to be nearly twice human consumption. Antibiotics are used not only for therapeutic or prophylactic purposes but also as growth promoters – especially in countries where such practices are still permitted [4].

Given the cross-sectoral use of antibiotics, a coordinated response is essential. In response to the escalating threat of antimicrobial resistance (AMR), the international community has increasingly endorsed the One Health approach. This interdisciplinary framework recognises the intrinsic interconnectedness of human, animal, and environmental health, and underscores the necessity of coordinated action among medical professionals, veterinarians, public health experts, and environmental scientists [5]. AMR is widely regarded as a prototypical One Health challenge, given its capacity to transcend species barriers and environmental boundaries, thereby posing a significant threat to global public health [6].

Since the late 1940s, antibiotics have been routinely used in animal husbandry, and since then, an increase in human infections caused by antibiotic-resistant bacterial strains has been observed [7]. The improper use of antibiotics in livestock farming can lead to the presence of antibiotic residues in food products of animal origin, such as milk, eggs, or meat, posing a potential health risk to consumers [8]. According to scientific literature, the presence of such substances in food can contribute to the selection and spread of antibiotic-resistant bacteria, facilitate their transmission to humans, and cause adverse effects such as AMR, allergic reactions, and toxic effects on the human body [1]. The World Health Organization (WHO), the American Medical Association, and the American Public Health Association have called for a ban on the use of antibiotics for growth promotion and have established guidelines aimed at restricting such practices [9]. As a result, the presence of drug residues, including antibiotics, in food at levels exceeding the maximum residue limit (MRL) set by international regulatory bodies is considered a violation of current legislation. Moreover, strict adherence to withdrawal periods, as well as physico-chemical analyses to confirm that the concentrations of active substances or their metabolites do not exceed established thresholds, is required before a food product can be approved for market distribution [8]. Food contaminated with antibiotic residues above the MRLs poses a serious threat to human health and is therefore a significant and ongoing public health concern [1]. This review article aims to discuss the pathways through which antibiotic residues can enter food at various stages of production and to summarize the consequences for human health. It will also outline the regulations governing the use of antibiotics and medicinal substances by food producers.

MATERIAL AND METHODS

This study is a review based on an analysis of the available scientific literature, reports from international institutions, and current legislation concerning the presence of antibiotics in food and their impact on human health. A comprehensive search was conducted using databases such as PubMed, ScienceDirect, Scopus, Google Scholar, and the European legal database EUR-Lex to obtain reliable and up-to-date information. Priority was given to publications from the last decade; however, older sources that significantly contributed to the development of the field were also included when substantively justified. The literature search was conducted in English between January and April 2025. Keywords used during the search included, but were not limited to: "antibiotic residues," "veterinary antibiotics," "food-producing animals," "antibiotic resistance," "human health," and "food contamination." These terms were selected to best reflect the thematic scope of the study, focusing on antibiotic residues from animal production, their presence in food, and their potential impact on human health and the development of microbial resistance. The search yielded 231 results. The selection of sources was based on their recency, scientific credibility (including peer-reviewed status), relevance to the topic – such as the presence of antibiotics in food, their health implications, or legal frameworks – and the availability of full-text articles. Both primary empirical studies and review articles were analysed, along with reports from key institutions including WHO, the European Food Safety Authority (EFSA), the European Centre for Disease Prevention and Control (ECDC), and the United States (US) Food and Drug Administration (FDA). A separate section focused on the analysis of legislation currently in force within the European Union (EU) and selected non-EU countries. This included regulations of the European Parliament and Council, national monitoring programmes, and documents regarding residue limits for pharmacologically active substances in food. The collected data were qualitatively analysed and organised according to thematic categories, with particular attention to their implications for public health and the environment. It should be noted, however, that the data presented in the literature are not always consistent. Significant differences between publications are often attributable to geographical context – such as epidemiological data from countries at different stages of economic development. These differences may pertain both to data collection methodologies and to actual levels of risk. Sector-specific variation is also relevant, as data from the pork, poultry, or dairy sectors can differ substantially. Inconsistencies may also stem from divergent definitions and classifications used across studies. Despite prioritising the most recent sources, it is important to acknowledge that not all included publications are fully up to date due to the rapidly evolving nature of legislation.

DISCUSSION

Pathways of antibiotic entry into the food chain

The preservation of food with additional substances represents an innovation in the food industry [10]. Moreover, food products may become contaminated during production due to environmental chemicals, residues from animal husbandry, or intentionally added substances [11]. Antibiotics, whether naturally occurring or synthetically introduced during processing, can also be deliberately incorporated into food as preservatives. Their primary function is to inhibit spoilage and extend the shelf life of food products [12].

Animal husbandry

One indirect route through which antibiotics may enter the food chain is their use during the animal husbandry stage. This sector is regulated by numerous standards that address animal welfare, product safety and quality, production efficiency, and public health protection [2]. All relevant guidelines for livestock breeders are outlined in the Animal Health Code [13] whereas food safety and the use of veterinary medicinal products in the EU are governed by regulations such as Regulation (EU) 2019/6 and Implementing Regulation (EU) 2022/1286, which aim to restrict the prophylactic use of antimicrobials in groups of animals. Unfortunately, many of these regulations are disregarded in large-scale production of pigs, cattle, and poultry, where the primary focus is often on maximizing productivity and profit, frequently at the expense of animal welfare and consumer safety [14,15]. In intensive farming systems, animals are often kept in environments that severely restrict their movement, preventing the expression germ of natural, species-specific behaviors. Additionally, animals are commonly subjected to painful zootechnical procedures, such as beak trimming in poultry, tail docking in pigs, and castration without anesthesia [16]. These practices contribute to elevated stress levels, suppressed immune function, and increased susceptibility to disease. Under such conditions, infectious diseases spread rapidly among densely confined animal

populations [17], necessitating the routine administration of drugs, typically via feed or drinking water [18,19].
Veterinary drugs include antimicrobials (such as antibiotics), growth promoters, sedatives, anticoccidials, non-steroidal anti-inflammatory drugs (NSAIDs), and anthelmintics [20]. The highest use of antimicrobials is observed in pig (45%), poultry (33%), and cattle (22%) farming, as confirmed by the FDA's 2023 report [21,22]. In a 2019 study conducted in Lebanon, Jammoul and El Darra [23] found residues of antibiotics in chicken meat samples, including tetracycline (17%), oxytetracycline (10%), doxycycline (3.75%), amoxicillin (18%), ampicillin (15%), and penicillin (13%). These findings demonstrate that antibiotics commonly used in animal husbandry can accumulate in animal tissues, ultimately reaching consumers through food. Due to the risks associated with this phenomenon, the EU banned the use of antibiotics for growth promotion in 2006. Studies on poultry meat have shown that countries such as Germany, Lithuania, and Poland have not fully complied with relevant veterinary drug regulations [24]. This is noteworthy given that the 2022 EFSA report indicated an overall non-compliance rate of only 0.18% across all sample types. Further research by Akhmet et al. [25] that meat imported from Russia, Ukraine, and the US contained antibiotic residues exceeding MRLs. Improper antibiotic use in livestock not only leads to tissue accumulation but also affects animal-derived products such as milk and eggs [26]. This is primarily due to the failure to observe appropriate withdrawal periods and incomplete veterinary record-keeping [27,28,29]. The extent of antibiotic accumulation in tissues varies depending on the pharmacological and pharmacokinetic properties of the drugs and the animal species involved [30]. Factors contributing to the exceedance of permitted levels in food products include farmers' lack of knowledge, intentional non-compliance, and insufficient regulatory oversight [31]. Moreover, many developing countries lack effective monitoring systems to detect pharmacological contaminants in food [32].
The development of aquaculture is also associated with significant antibiotic use [33]. In this sector, pharmacological treatments are administered orally, by injection, or added directly to water bodies [34]. Studies have confirmed the presence of antibiotic residues in aquatic environments, including both water and sediment samples, indicating environmental contamination [35,36,37].
Such intensive use of antibiotics in livestock and aquaculture contributes to their accumulation in final food products.

Crop production

As one of the most dynamic ecosystems on Earth, soil plays a crucial role in the cycling of substances [33]. It serves as a key substrate in agriculture, where it is intensively utilized and periodically requires nutrient enrichment. A common organic fertilizer used for this purpose is manure, which supplies plants with essential nutrients [38]. However, manure, although organic, often contains pharmaceutical residues stemming from veterinary drug use. This contamination results from the bioavailability of antibiotics in livestock, which can range from 30% to 90%, depending on the specific compound and the animal species to which it was administered [39].
Following metabolism, antibiotics are primarily excreted via urine and feces, subsequently entering the soil through the application of animal manure. From there, these residues may leach into groundwater and surface water systems [40,41]. A 2019 study conducted by Chinese researchers confirmed that antibiotic resistance can develop in soil microbiota within just two months of cattle manure application [42].
Each class of antibiotics behaves differently in the environment. For example, sulfonamides are most frequently detected in surface and groundwater, whereas tetracyclines and fluoroquinolones exhibit long half-lives in soil, where they may persist for several months [43]. The presence of antibiotics in soil can lead to the development of antimicrobial-resistant bacteria, that can colonize crops and subsequently enter the human gastrointestinal tract [44]. Several studies have demonstrated that bacteria can acquire resistance due to the application of animal-derived manure in agricultural production [45,46,47,48,49].
Mulchandani et al. [50] emphasize that in countries such as China, Brazil, India, and the United States, the contamination of agricultural land with zoonotic manure is considered a major contributor to the spread of antibiotic resistance genes. Additionally, areas characterized by intensive livestock farming tend to experience reduced soil and groundwater quality due to antibiotic contamination, with negative effects on microbial biodiversity [51]. While the commercial use of compost products offers numerous benefits, it may also facilitate the dissemination of resistance genes in the environment. However, composting presents an opportunity for the biodegradation of pharmaceuticals, which could help mitigate the risk of spreading antibiotic resistance [52,53].
It is also notably that plants are capable of absorbing antibiotic residues from manure applied to soil [54].

These residues may disrupt normal plant growth by inducing abiotic stress [55,56,57]. Furthermore, the consumption of vegetables and fruits grown in areas where sewage or animal manure has been applied can lead to the ingestion of antibiotics accumulated in plant tissues [58]. The extent of accumulation and the specific plant organs affected depend on the type of antibiotic involved [59]. A 2022 study found that tetracyclines exhibited the highest concentrations among common classes of antibiotics in plants, with the greatest accumulation observed in root systems [60,61,62].

Additives in processed food products

Following the production process, food products must be appropriately packaged. At this stage, food-contact packaging increasingly incorporates antimicrobial materials to extend shelf life [63,64]. Various strategies are employed to achieve antimicrobial activity, including the addition of sachets containing volatile agents, embedding active substances into biopolymers, coating or grafting agents onto polymer surfaces, and the use of internal polymers or antimicrobial pads [65]. In light of growing bacterial resistance to antibiotics, packaging technologies increasingly rely on natural and synthetic bactericidal agents, such as preservatives and silver nanoparticles, to inhibit microbial growth [66,67,68]. Antibiotics may also be incorporated into halloysite nanotubes, which offer enhanced thermal stability, extended product shelf life, and controlled antimicrobial release [69,70].

Additionally, bacteriocins – antimicrobial peptides naturally synthesized by bacteria – are utilized in food preservation, including within packaging systems [71]. Nisin, a well-characterized bacteriocin, has been officially approved as a natural food-grade antimicrobial additive. It is effective against various foodborne pathogens, such as *Listeria monocytogenes*, as well as a wide range of Gram-positive bacteria [12,72,73,74,75].

However, antibiotic-impregnated packaging remains at the experimental stage and is not approved for use in food applications in either the EU or the US.

Adverse health effects

As previously discussed, veterinary pharmaceuticals – particularly antimicrobial agents – are frequently detected in animal-derived food products. The persistence of these compounds is governed by multiple factors, including their pharmacodynamic and pharmacokinetic properties and the subsequent physicochemical processing of animal tissues. However, the principal driver is the improper use of antimicrobials and non-compliance with mandated withdrawal periods. Alarmingly, recent years have seen a marked increase in food-borne infections caused by AMR pathogens, underscoring the direct link between antimicrobial use in livestock and the spread of resistance mechanisms among bacterial populations [30,34].

The WHO has identified AMR as one of the most critical threats to global health security in the 21st century [76]. Although the direct toxicological impact of antimicrobial residues in food on human physiology remains inadequately elucidated, the potential for horizontal gene transfer of resistance determinants via the food chain is now recognized as a major public-health hazard [77].

From a regulatory standpoint, residues that remain within the MRLs are considered toxicologically acceptable. This classification is based on lifetime--exposure models that have shown no significant adverse effects in humans [78]. In contrast, concentrations exceeding established MRLs are linked to a spectrum of health risks, including the promotion of AMR, immunological hypersensitivity reactions, genotoxicity, nephrotoxicity, hepatocellular injury, disruption of intestinal-microbiota homeostasis, and reproductive toxicity. Hematotoxic effects and a potential role in carcinogenesis have also been proposed in the context of chronic exposure [2,30,34].

Because most antimicrobials are excreted in urine, they can reach aquatic environments via municipal wastewater systems and effluent discharge, thereby contributing to environmental contamination. This is particularly relevant to aquaculture, where antimicrobials are routinely administered for prophylaxis and therapy. Environmental exposure, combined with the therapeutic use, facilitates bioaccumulation in fish tissues. Human consumption of such products – especially when eaten raw – may therefore constitute an additional, often underestimated, route of exposure. In an experimental study, Herman et al. [79] assessed common culinary techniques for their ability to reduce antimicrobial-residue levels in fish. Thermal processing – boiling, frying, or baking for 10 minutes – achieved only moderate reductions; complete degradation was not possible [2,34].

Antibiotic resistance

The emergence and spread of antibiotic-resistant bacteria represent the most critical consequence of antimicrobial overuse. Projections suggest that by 2050, deaths attributable to AMR infections could exceed those caused by cancer [2,34,80]. This scenario portends higher infection rates, more frequent and prolonged hospital stays, increased mortality, and substantially greater healthcare expenditures.

Remarkably, even minimal environmental concentrations of antibiotics can exert selective pressure sufficient to drive resistance in bacterial populations [81]. A landmark finding in 2001 was the isolation of an antibiotic-resistant *Salmonella* strain from ground meat, demonstrating that resistant pathogens can be transmitted to humans through contaminated animal products. Subsequent studies confirmed that resistant strains such as *Salmonella* spp., *Campylobacter* spp., and methicillin-resistant *Staphylococcus aureus* (MRSA) can enter the human body via food [35].

AMR is defined as the ability of microorganisms – including bacteria – to survive and proliferate in the presence of agents that previously inhibited or killed them [82,83]. The primary driver of AMR is inappropriate and excessive antimicrobial use. Resistance determinants are transmitted to pathogenic and commensal species through spontaneous mutation and via horizontal (conjugation, transformation, transduction) or vertical gene transfer [84,85,86]. Transmission to humans may occur through ingestion of contaminated food, direct contact with animals, or environmental exposure [87]. Resistance genes can persist in environmental reservoirs even after selective pressure is removed [88].

We are thus entering an era in which many once-effective antibiotics have lost therapeutic utility [89]. According to the ECDC, food-producing animals are reservoirs for AMR pathogens such as *Salmonella* and *Campylobacter*, both primarily transmitted to humans via ingestion [90].

The WHO has designated a group of multidrug-resistant pathogens – the ESKAPE organisms (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* spp.) – as high-priority threats because they “escape” standard antimicrobial treatments [91,92]. Consequently, routine hospital procedures now carry a heightened risk of infection with organisms that are increasingly refractory to treatment [93].

A 2022 global systematic analysis of AMR further highlighted the clinical burden of this crisis: in high-income countries, *Staphylococcus aureus* and *Escherichia coli* accounted for nearly half of all AMR-associated deaths, underscoring the urgent need for coordinated international strategies [94].

Toxicity

Although antibiotic toxicology is well characterized in therapeutic contexts, accumulating evidence indicates that chronic dietary exposure to low-level residues can also produce adverse effects. Such residues, present in animal-derived foods, may exert biological impacts that are modulated – amplified or attenuated – by the gut microbiota.

Acute toxicity is rare and usually occurs only when MRLs are exceeded, or banned substances are present. Nevertheless, scientists are increasingly concerned about long-term, low-dose exposure. Subtherapeutic antimicrobial levels ingested chronically have been linked to alterations in gut microbiota composition, immune dysregulation, and heightened susceptibility to infections, allergic responses, and chronic inflammatory conditions.

Chronic exposure can compromise intestinal homeostasis and weaken systemic immunity, predisposing individuals to both gastrointestinal and extra-intestinal diseases [95]. Emerging data also suggest that even residues below MRLs may affect hepatic metabolism, disrupt endocrine function, and foster the selection of intermediate-resistant bacterial strains.

Allergic reactions

Residues of certain antibiotics have been associated with hypersensitivity reactions. β-Lactam antibiotics are among the most allergenic, and even trace exposure via food can elicit cutaneous manifestations such as maculopapular rashes, erythema multiforme, or exfoliative dermatitis. Severe systemic reactions, including anaphylaxis, can occur even when exposure is limited to sub-MRL concentrations [1,96].

Tetracyclines are also reported to cause dermatologic reactions and phototoxicity, particularly in children [30]. Cephalosporin residues – structurally related to penicillins – may provoke a wide range of adverse effects, from mild eruptions and desquamation to severe conditions such as thrombocytopenia, toxic epidermal necrolysis, and Stevens-Johnson syndrome [8].

Carcinogenic effects

Chronic dietary exposure to antibiotic residues can disrupt intestinal microbiota homeostasis. Such dysbiosis permits the overgrowth of opportunistic pathogens, potentially leading to severe gastrointestinal conditions – including pseudomembranous colitis – and, in the long term, colorectal carcinogenesis [97].

Chloramphenicol is considered hematotoxic and has been associated with irreversible aplastic anemia. However, according to the EFSA, it is not classified as a carcinogen. In the EU, chloramphenicol is banned for use in food-producing animals, with no established MRL, and the primary risk is related to occupational exposure rather than dietary intake. Other antimicrobials – such as sulfamethazine, oxytetracycline, and furazolidone – have demonstrated carcinogenic potential and immunopathological effects in experimental models [30,34].

A study by Hou et al. [98] highlighted the toxicological impact of several commonly detected antibiotic residues – specifically quinolones, tetracyclines, macrolides, β-lactams, and sulfonamides – on male reproductive health. Chronic ingestion of these residues was associated with impaired spermatogenesis, reduced sperm motility and concentration, decreased testicular weight, histological damage, and an elevated risk of testicular neoplasia. These findings underscore the systemic implications of long-term, low-dose exposure to antibiotic residues in the food chain.

Legal aspects, monitoring and prevention

In the post-war period, when food scarcity was a significant concern, a serendipitous discovery occurred in the late 1940s and early 1950s. The addition of streptogramin to chicken feed markedly enhanced growth rates. Shortly afterwards, in 1949, a similar effect was observed in poultry fed by a post-fermentation product containing trace amounts of chlortetracycline produced by *Streptomyces aureofaciens* [99]. Subsequent studies confirmed that antibiotics also stimulated weight gain in pigs and cattle [100]. Initially, all antibiotics were approved for usage, even though some failed to improve growth, and many were prohibitively expensive. In the late 1960s, the first public debate on using antibiotics solely as growth promoters culminated in the UK "Swann Report" [101]. As interest in the topic grew, more studies documented the adverse consequences of antibiotic use in livestock production, leading to increasingly strict and regulated authorisation regimes [101,102].

Regulations in the EU

The EU began regulating antibiotic use in veterinary medicine with Council Regulation 2377/90, which was subsequently amended and updated, culminating in current Regulations (EU) 2019/6 on veterinary medicinal products and (EU) 2019/4 on medicated feed [103,104]. Because the same classes of chemo-therapeutic agents are used in both human and veterinary medicine, posing a public-health risk, Member States must draw up and implement an official feed-control plan each year [105]. The European Parliament and Council established proce-dures for determining MRLs for pharmacologically active substances in foodstuffs of animal origin under Regulation (EC) No. 470/2009 of 6 May 2009, with specific MRLs provided in Commission Regulation (EC) No. 37/2010 of 22 December 2009 specified the numerical MRLs [106]. Additionally, EU operates the Rapid Alert System for Food and Feed (RASFF), which is designed to enhance official controls in the domain of food safety. The primary objective of the system is to facilitate the rapid exchange of information among competent authorities in EU member states and associated countries. Through RASFF, data concerning food, feed, and food contact materials that may pose risks to human, animal, or environmental health are shared. The system also outlines specific measures to be implemented when such potentially hazardous products are identified [107].

National regulations in Poland

As an EU Member State, Poland is obliged to implement programs for monitoring antibiotic residues in food. The key instrument is the National Programme for the Control of Certain Substances and Residues of Chemical, Biological and Medicinal Products in Animals and Food of Animal Origin, based on Council Directive 96/23/EC of 29 April 1996 and in force since 2004 [108].

Examples of non-EU countries

According to Nowacka-Kozak et al. [109] every antibiotic authorised for livestock use in the EU has a species- and tissue-specific MRL. South American countries lack comparable regulations, which poses a public health risk if sanitary rules governing imports into the EU are not followed [110]. In Ukraine, similar to the EU, the use of antibiotics for growth promotion in livestock is prohibited [111]. In the US, policy measures have also been progressively tightened. Since January 2017, the use of medically important antimicrobials for growth promotion has been banned, although prophylactic use remains permissible [112]. China, one of the world's largest consumers of veterinary antibiotics, issued by the Ministry of Agriculture and Rural Affairs a 2019 regulation phasing out medicated feed additives, and updated these guidelines in 2024, banning certain medicated substances altogether [113,114].

CONCLUSIONS

The presence of antibiotics in food is a complex and multifactorial public health issue that originates from practices in animal husbandry, agriculture, and subsequent food processing and packaging. Residues of antimicrobial agents have been detected in meat, milk, eggs, vegetables, and fruits. These residues pose significant health hazards, including the development of AMR, hypersensitivity reactions, toxic effects on internal organs, carcinogenicity, and reproductive dysfunction. AMR, identified by the WHO as one of the most pressing health threats of the twenty-first century, substantially diminishes therapeutic efficacy and contributes to increased mortality and healthcare expenditures.

Although strict regulations exist in the EU and other industrialised regions, gaps in compliance remain, and insufficient surveillance in many developing countries creates worldwide consumer risks.

Final remarks

1. Reducing the use of antibiotics in animal husbandry is imperative and can be achieved through improved hygiene, vaccination, alternative interventions (probiotics) and the development of rapidly biodegradable drugs.
2. Rigorous enforcement of veterinary regulations – including adherence to withdrawal periods and maintenance of treatment records – is essential for minimizing residues in food.
3. Enhanced monitoring of the food supply, especially imports, should involve routine, sensitive testing for pharmaceutical residues.
4. Educating consumers about the hazards of antibiotic residues is crucial for informed dietary choices.
5. Further research is needed to clarify the long-term effects of chronic, low-level antibiotic exposure on gut microbiota, metabolic health, and resistance development.
6. International cooperation, based on the One Health concept, should include data sharing, regulatory harmonisation and joint risk mitigation strategies.
7. Coordinated action at local, national and global levels is indispensable for curbing the spread of antibiotic resistance and safeguarding public health and food security.

Authors' contribution

Study design – J. Kasperczyk
Data collection – K. Lis, G. Mysłek
Manuscript preparation – D. Nicz, K. Lis
Literature research – G. Mysłek, D. Nicz
Final approval of the version to be published – J. Kasperczyk

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