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Antimicrobial Resistance: Navigating An Unfolding Public Health Crisis

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Abstract Antimicrobial resistance (AMR) has public health and economic implications and has emerged as one of the leading public health threats in the world. It is estimated that bacterial antimicrobial resistance caused around 1.27 million human deaths globally in 2019. The overuse and misuse of antimicrobials in humans, animals, and plants are primarily responsible for the development of drug-resistant pathogens. AMR affects different countries regardless of income levels. The drivers and consequences of AMR are aggravated by poverty and inequality, affecting low- and middle-income countries the most. Antimicrobial resistance can occur when the parent compounds, their metabolites, and associated impurities of veterinary drugs in present in any edible portion of an animal product. It can result in severe consequences for humans if the concentration level consumed is higher than the standard residue limits. Residues of veterinary medicines are defined as pharmacologically active substances, principles, or degradation products and their metabolites that remain in animal-origin food obtained from animals that have been administered medicine. This review indicates the occurrence and public health impacts of antimicrobial and drug resistance. The most frequent reasons why antibiotic residues might be found in animal-derived food are overuse of antibiotics, negligence in observing withdrawal periods, and incorrect dosage forms. If antibiotics are used as "insurance" against disease-related livestock losses, misuse of antibiotics and the presence of antibiotic residues in food products can be difficult to control. These kinds of situations are common in many poor countries, where the need for antibiotics rises due to the incidence of infectious diseases. Products made from animals that have these residues in them may cause hypersensitivity reactions, bone marrow depression, cancer, mutagenicity, teratogenicity, and disturbance of normal gut flora. They may also cause increased resistance to antibiotic treatments. Therefore, adherence to strict withdrawal timings and guidelines is necessary to guarantee that animal products are safe for human consumption.

Keywords: *Antibiotics, Antimicrobials, Antimicrobial resistance, Food chain, Public health*

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1. Introduction

Antibiotics are compounds that either prevent or eradicate microorganisms from multiplying in a natural, synthetic, or semi-synthetic way. Because they are readily available and reasonably priced, antibiotics have been used extensively in the dairy, cattle, poultry, aquaculture, and beekeeping industries all over the world. Bacteria are increasingly developing resistance to a wider range of antibiotics. This antimicrobial resistance (AMR) can spread through horizontal transfer from already resistant bacteria or emerge through new genetic mutations [1]. Additionally, bacteria may possess intrinsic resistance to various classes of antibiotics, which contributes to a baseline level of resistance within a specific ecological niche. The complete collection of AMR genes within a microbiome is known as the "resistome." The bacterial intrinsic resistome is defined as the entirety of elements contributing to antibiotic resistance regardless of previous exposure to antibiotics [2]. Factors contributing to antimicrobial drug resistance encompass inadequate access to clean water, sanitation, and hygiene (WASH) for humans and animals as well as insufficient disease and infection control across households, healthcare settings, and agricultural sites. Limited availability and affordability of high-quality vaccines, diagnostics, and medications also play a critical role. The two primary zoonotic illnesses for which antibiotic resistance should be monitored are *Salmonella* species and *Campylobacter jejuni* [3].

Veterinarians employ antibiotics for therapeutic, prophylactic, dietary, and growth-related reasons. The escalating use of antimicrobials in livestock for health maintenance and production enhancement exerts considerable antimicrobial selection pressure, facilitating the proliferation of antibiotic-resistant bacteria [4,5]. Reports indicate that antimicrobial usage is notably higher in poultry and swine compared to cattle, raising significant concerns about the safety of consuming these animal products and contributing to environmental contamination with multidrug-resistant (MDR) bacterial strains [4]. These MDR bacteria can be transmitted to humans either directly through contact with live animals or animal waste or indirectly via the consumption of contaminated animal-derived products [6]. Consequently, human colonization with MDR bacteria may increase, heightening the risk of MDR bacterial infections [7]. The veterinary drugs are utilized globally and comprise a variety of chemical constituent kinds, such as agonists, antimicrobials, vaccinations, and antiparasitic [8]. These drugs have helped to increase the productivity and profitability of contemporary food-animal production by permitting earlier weaning, higher animal densities, carcass yield, and meat quality in addition to the use of less expensive feed sources [8]. The antimicrobials commonly employed in livestock production include tetracyclines, amprolium, penicillin, streptomycin, tylosin, aminoglycosides, lactams, macrolides, lacosamide, quinolones and sulfonamides [9]. A variety of drugs are used to treat parasites, including as pyrethroids, carbamates, nitrofurans, nitroimidazoles, stilbenes, anthelmintics, and amphenicols.

The benefit of using antibiotics in food animals properly is related to the drug's ability to combat infectious bacteria that can spread to humans in various ways. However, using antibiotics in food animals is not risk-free. The main antimicrobials, growth promoters, sedatives, anticoccidials, nonsteroidal anti-inflammatory drugs (NSAIDS), and anti-helminthics that might contaminate food are found in veterinary medicine and the increasing ability of the micro-organisms to survive and multiply in the presence of antibiotic doses that were formerly thought to be effective against them is a problem that is becoming more and more widespread on a global basis.

AMR impacts both human and veterinary medicine and is a serious emerging hazard to public health and food security. AMR has now increased to concerning proportions in a large portion of the world. Although global livestock production has been rapidly expanding and heading toward a scenario where the use of antibiotics is a necessary component of production, improper or excessive use of antibiotics can result in the development of antibiotic-resistant bacteria, which are the most common veterinary medicines that could contaminate food [10].

The past forty- years of research have shown that the main causes of AMR in East Africa are high levels of antibiotic use in small production systems, human-animal contact, the absence of a withdrawal period before humans can consume meat and dairy products from recently treated animals, and frequent or negligent antibiotic-use management (AMU), which is thought to be one of the main causes of the infectious diseases that AMR was initially unable to treat. Ethiopia has a high rate of drug use in various sectors of the economy, including public health and veterinary care. The government does not closely monitor the pharmaceutical industry or provide data on safe medication use in veterinary care. Moreover, food items have the potential to harbor bacteria resistant to antibiotics and act as good dispersal agents. Given this, food plays a crucial role in the extremely efficient transfer of AMR factors to consumer's digestive systems [11]. There is evidence that the cattle and the food they generate, including milk and meat, can act as reservoirs for human diseases due to the well-documented transfer of AMR bacteria to humans through the food chain [12].

Recent years have seen the emergence of several antibiotic-resistant viruses that can infect humans and spread throughout the food supply chain. Among these, antibiotic resistance in *Salmonella*, *Staphylococcus aureus*, and *Escherichia coli* poses a challenge to the global healthcare system [13,14,15]. Additional research conducted in Ethiopia in veterinary and public health contexts likewise discovered that the prevalence and antibiotic susceptibility of *Salmonella, E. coli, and S. aureus* were fragmented significantly [16]. Therefore, the objective of this communication is to present a critical review on antimicrobial drug resistance and its emerging global public health impacts.

2. Literature Review

2.1. Use of Antimicrobials in Food-Producing Animals

An increasing amount of evidence indicates a connection between the usage of antibiotics in food-raised animals and the emergence of resistance in prevalent diseases. The increasing reliance on intensive animal production systems to meet demand has led to the routine use of antimicrobials, a practice that not only sustains productivity but also perpetuates dependency on these drugs, raising serious concerns about animal welfare, public health, and the escalation of antimicrobial resistance [17]. Such resistance affects both human and animal health if these viruses get into the food chain. These antimicrobial uses whether for growth promotion, prevention, or therapeutic purposes are impacted by a variety of complex factors, which calls for the coordinated use of the required interventions. The principles underlying the responsible use of antibiotics and the control of resistance are similar to those that apply to humans [18].

2.2. Emergence of Antimicrobial Resistance

The first description of antimicrobial resistance in *Bacillus coli* (now known as *Escherichia coli*) early in the same year [19], shortly before the first use of penicillin to treat infectious diseases in humans began and not long after its discovery by Fleming in 1929. Since most antimicrobials used in medicine are naturally produced by soil microorganisms, it has been demonstrated for over 40 years [20] that these microorganisms are the source of many resistance genes currently found in clinically important bacteria. Another phylogenetic investigation [21] has shed light on the origins of resistance by suggesting that the advent of AMR genes in bacteria occurred well before the usage of antibiotics. However, a retrospective analysis showed that AMR was incredibly uncommon in clinical isolates before antibiotics were introduced [22]. This is important to understand because it offers compelling evidence for the pivotal role that AMU played in the emergence and spread of antibiotic resistance. AMR is, in fact, an old and natural component of environmental bacteria's genome.

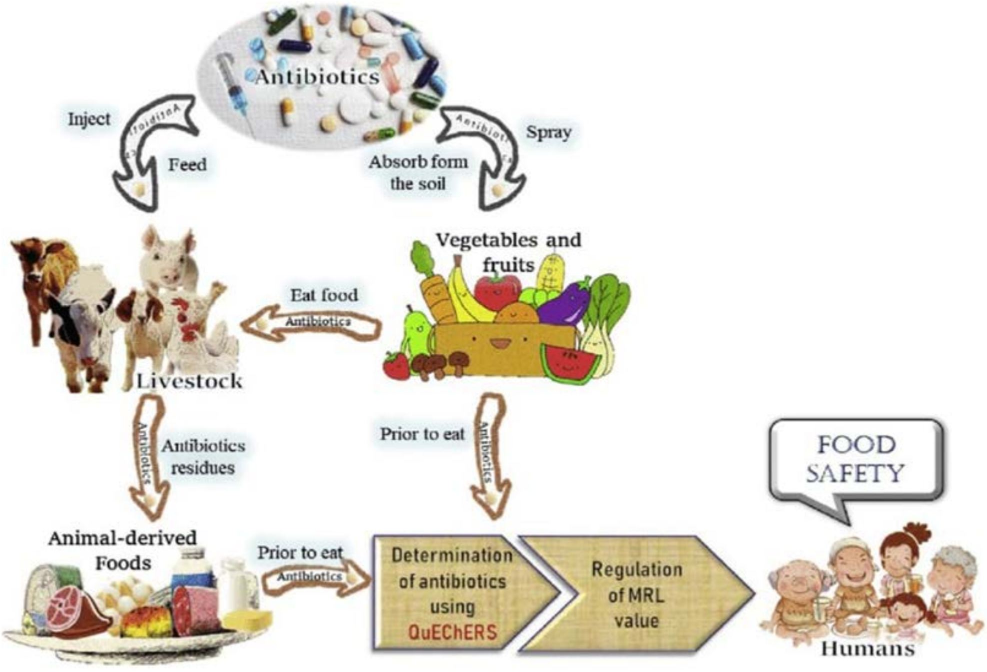

Figure 1. Antimicrobial usage in humans, animals and agriculture (Source: [4])

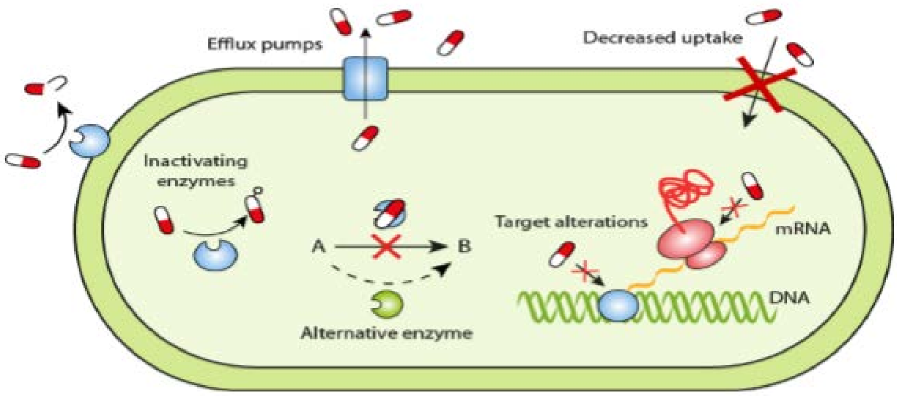

Figure 2. Mechanism of drug resistance development (**Source: [23]**)

2.3. Antimicrobial Use and Resistance Development

The use of antimicrobial medications is the main cause of resistance. Antimicrobial medications are utilized in a range of contexts, including animal-related contexts such as veterinary clinics, farms, and feedlots, as well as hospital, outpatient, and long-term care settings. They are frequently used to treat or prevent illness in animals raised for food. Antimicrobials are added to almost all animal feed that is growing to prevent disease. These levels range from what are known as "sub-therapeutic concentrations" to full therapeutic doses. Moreover, food processing facilities employ antimicrobial chemicals to prevent the growth of bacteria that compromise the final goods' safety and quality [7].

Despite a decade of research and a substantial amount of scientific evidence, some skeptics continue to dispute the connection between the use of antimicrobial drugs on farms and the development of antimicrobial resistance in human diseases (Figure 2). The amount of antibiotics used in food animals is thought to be higher than that used in humans globally, and almost every class of antibiotic used in humans is also utilized in food animals. The overuse and abuse of antibiotics are acknowledged as two of the main factors contributing to acquired antibiotic resistance (AMR), both directly and indirectly. This is because these practices place selection pressure on environmental bacteria as well as the microbiota of humans and animals [24].

It has been reported that the usage of antibiotics can unblock gene expression, which could promote mutations or the formation of resistance genes in bacteria [25]. Gene swapping allows the resistance gene to be transferred from agricultural and food-producing bacteria to human disease-causing microorganisms. The ability of a resistant pathogen to spread from one individual to numerous others poses a concern to global public health. Further, it was observed that persistent antibiotic residues in feed and animal dung may contaminate soil and water and affect the aquatic and environmental microbiomes [26]. It is anticipated that antibiotic residue concentrations in these agricultural settings will be elevated, which poses a significant risk factor for the development of antimicrobial resistance (AMR). Based on estimates, 75 to 90 percent of antibiotics administered in cattle are excreted, generally unmetabolized [7].

Long-term use of antibiotics has been linked to the development of multidrug resistance in aquaculture and intestinal bacteria in humans and other animals [27]. Multiple drug resistance (MDR) bacterial strains may potentially be selected as a result of antimicrobial combination therapy. Because they encourage genetic and phenotypic heterogeneity in exposed bacteria, low dosages of antibiotics (i.e., residual levels, sub-lethal or sub-therapeutic dosages) are additional factors contributing to resistance [28,26].

Small-scale farming operations supply the majority of the dairy markets in most sub-Saharan African nations. Antibiotic treatments for sick dairy cows are frequently administered; the most often reported cause of drug residues in marketed milk is noncompliance with the withdrawal time/periods following these treatments [29]. Additionally, they are employed proactively in intense production to stop diseases before they start and spread.

Milk can contain feed bacteria that produce glycerol from organic boric acid. These pathogens show antibiotic resistance, and raw milk products have been linked to the spread of antibiotic-resistant organisms from farm environments to human populations [30]. In underdeveloped nations, where local laws governing maximum tolerance limits for marketed products may not exist and advised withdrawal periods are disregarded, there appears to be a heightened danger to public health from antibiotic residues [31].

2.4. Antimicrobial Resistance

2.4.1. Antimicrobial Agents and Mechanism of Action

The word "antibiotics" refers to a large range of chemical substances that can be produced synthetically, semi-synthetically, or spontaneously [32] aimed at suppressing or eradicating bacterial growth. They are separated into two categories: antibiotics with narrow or broad-range activity and those with bacteriostatic or bactericidal activity. The majority of antibiotics used in food animals fall into five broad categories. Some of these include the aminoglycosides gentamicin and streptomycin, the macrolides- erythromycin and tetracyclines-oxytetracycline, tetracycline and chlortetracycline, the beta-lactams (ß-lactams)- penicillins and cephalosporins, and the sulfonamides which also include sulfamethazine [33].

Depending on the antibiotic, bacteria can be killed or their ability to proliferate inhibited in a variety of ways. Accordingly, the medication can either destroy or stop the growth of bacteria by blocking the manufacture of cell walls, blocking the activity of nucleic acids, causing damage to cell membranes, or stopping the synthesis of proteins [34]. Cell wall production is inhibited by the β-lactam antibiotic. Penicillin-binding proteins are the principal targets of β-lactam drugs. The β-lactam ring is thought to resemble the D-alanyl D-alanine segment of the peptide chain, which is often bound by PBP. PBP interacts with the β-lactam ring and isn't available for peptidoglycan production. Bacterial lysis results from rupture of the peptidoglycan layer [35].

Antimicrobials that target the 30S or 50S subunit of the bacterial ribosome inhibit protein synthesis. The class of drugs known as aminoglycosides (AGs) is one of them. These are positively charged molecules that form large pores that allow antibiotics to enter the bacteria by binding to the negatively charged outer membrane (OM). The interaction between AGs and the 30S sub-unit's 16S r-RNA results in misreading and premature termination of mRNA translation. Tetracyclines like tetracycline, chlortetracycline, doxycycline, or minocycline also impact the conserved sequences of the 16S r-RNA of the 30S ribosomal sub unit by preventing t-RNA from binding to the A site [36].

Other drugs, such as macrolides, target the conserved sequences of the peptidyl transferase core of the 23S r-RNA of the 50S ribosomal subunit to alter the early step of protein synthesis, known as translocation. This causes an early separation of unfinished peptide chains. Agents like trimethoprim act at a later stage of folic acid synthesis and inhibit the enzyme dihydrofolate reductase. The sulfonamide drug classes work by competitively inhibiting dihydropteroate synthase with a higher affinity for the enzyme than the natural substrate, p-amino benzoic acid [36].

2.4.2. Mechanisms of Spread of Antimicrobial Resistance between Animals and Humans

It is described that humans can come into direct touch with animals or their waste in the environment, which can spread both pathogenic and non-pathogenic resistant bacteria [7]. They can also spread through food. The local and global transmission of resistant bacteria can also be significantly influenced by fomites. Genetic elements of the same or different strains or species of bacteria can also transfer genetically to confer resistance. This may occur in any environment where susceptible bacterial populations can come into contact with resistant bacteria, like the human or animal gut, slurry applied to agricultural soil, or aquatic environments [37].

Resistance genes have the potential to spread from humans to poultry farms, raising concerns about bacterial contamination in water, food crops, and animal feed due to environmental bacteria that acquire resistance. Such contamination can facilitate the exchange of resistance traits with commensal or pathogenic species within the gut microbiota of animals or humans, thereby presenting significant health risks for both populations as shown in Figure 3 [38].

Nevertheless, there is little information available regarding the significance of this route in the transmission of resistance, and the environmental fates of various antimicrobials vary. It is imperative to acknowledge that residues originating from pharmaceutical manufacture or human antimicrobial treatment may also exert selection pressure on ambient bacteria as shown above in Figure 3 [21].

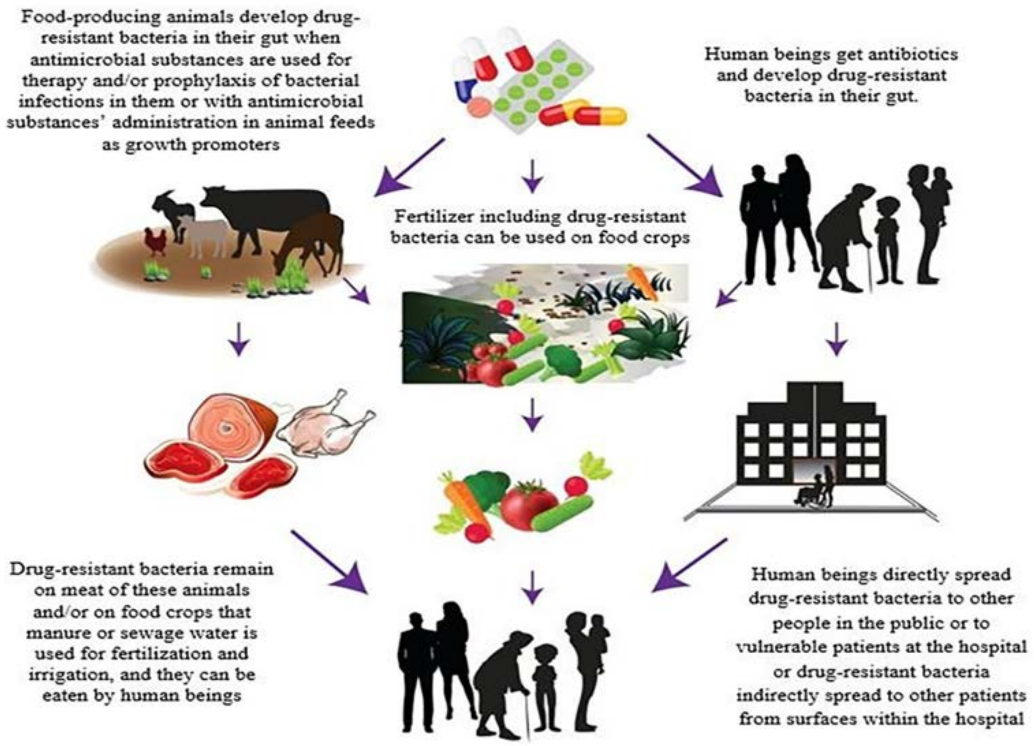

Figure 3. Spread of antimicrobial resistance between animals and humans (Source: [39])

2.5. Great Challenge of Antibiotic Resistance

Antibiotic resistance is a result of the regular use of antibiotics in livestock husbandry for growth promotion and prevention, which favors commensal and pathogenic microorganisms. Antibiotic resistance has an ecological impact since the majority of these drugs are not completely metabolized and are instead released into the environment as waste products. These waste products still possess the ability to affect the population of bacteria and encourage antibiotic resistance. It has been documented that mutagenesis occurs randomly and spontaneously due to the low quantities of these antibiotics in the environment [40].

Antibiotics, antibiotic-resistant bacteria, and the genes conferring resistance are now recognized as persistent environmental reservoirs. This reservoir poses a significant public health challenge globally, as resistance genes have the capacity to transfer not only between bacterial strains of the same species but also across distinct species. This transferability is facilitated by mobile genetic elements such as integrons, transposons, and plasmids, which serve as vectors for the spread of antibiotic resistance traits [41].

Horizontal gene transfer (HGT) or lateral gene transfer (LGT) is the technique by which these resistance genes are conveyed by transformation, conjugation, and transduction [42]. Due to gene exchanges across different species of bacteria, these mechanisms are the source of the global increase in antibiotic resistance. The dissemination of numerous antimicrobial-resistance determinants and the cause of an epidemic in nosocomial and community infections have both been connected to LGT because of its capacity to transmit resistance to multiple antibiotic classes, including multidrug resistance. Additionally, the use of broad-spectrum antibiotics puts the bacterial flora under selective pressure, which increases the establishment of multidrug-resistant bacteria and the subsequent creation of new antibiotic-resistant bacteria that need painful treatment cycles [43].

3. Public Health Impacts

3.1. Public Health Impacts

The consumption of food products containing antibiotic-resistant pathogens presents a critical public health threat due to potential treatment failures. Such exposure may facilitate the spread of antibiotic-resistant bacteria and is associated with numerous adverse health effects, including immunopathological responses, autoimmune disorders, and carcinogenic risks linked to agents like methazine, oxytetracycline, and furazolidone. Additional health concerns include mutagenic potential, nephrotoxicity (notably with gentamicin), hepatotoxicity, bone marrow suppression related to chloramphenicol exposure, and hypersensitivity reactions, particularly with penicillin [44].

3.1.1. The Development of Drug Resistance

Antimicrobial resistance has been associated with the use of antibiotics in animal feed, which can compromise the efficacy of medical treatments in both humans and animals. In some cases, this resistance can render medications entirely ineffective, posing significant challenges to managing infections. A resistant microorganism can enter people directly through contact or indirectly through animal products and byproducts (such as milk, eggs, etc.) given the proven fact of an animal to human microbial resistance transfer [45].

3.1.2. Allergy or Hypersensitivity Reactions

The use of penicillin is associated with IgE-mediated allergic anaphylaxis [46]. These allergic reactions, which are typically mediated by IgE, may occur after medications or macromolecules like protein, fats, and carbs are administered. It is confirmed that an estimated 4–11% of people in the world are thought to be penicillin allergic. People in this category who eat animal products that contain residues of penicillin run the risk of becoming allergic, which can cause a skin rash or potentially life-threatening anaphylaxis [45]. Skin reactions in humans exposed to sulfonamide range from a mild rash to severe toxidermia. Nevertheless, ingesting animal products with relatively modest levels of sulfonamides did not directly cause this negative reaction. Research has also demonstrated a link between allergic reactions to macrolide antibiotics (such as erythromycin and clarithromycin) and hepatic liver cell damage [47].

3.1.3. Carcinogenic Effect

The term "carcinogen" designates any substance that exhibits carcinogenic activity or promotes the process of carcinogenesis, which is the development of cancer. In contrast, "carcinogenic" refers to substances or agents that possess the capacity to alter an organism's genetic makeup, facilitating the proliferation of cells in a manner that can lead to malignancy. DNA, RNA, proteins, glycogen, phospholipids, and glutathione are the intracellular components that covalently attach to carcinogenic residues [48]. Diethylstilbestrol (DES) is a hormone-like substance that was used to produce animals for food, but its high carcinogenic effects led to its ban. The International Agency for Research on Cancer (IARC) indicates substantial evidence demonstrating the carcinogenicity of metronidazole in animal models; however, the evidence is insufficient to classify it as carcinogenic in humans [49].

3.1.4. Disruptions of Normal Intestinal Flora

The microbiota in the gastrointestinal tract plays a crucial role in human physiology by establishing protective barriers and preventing the colonization of harmful pathogens within the digestive system. However, studies have shown that the even therapeutic use of antibiotics can alter or disrupt the ecological composition of intestinal flora. The degree of change is contingent upon the antimicrobial drug's dosage, mode of administration, bioavailability, metabolism, duration of exposure, and diffusion throughout the body, including the excretory pathway. There have been reports of broad-spectrum antibiotic use disrupting gut flora. Medications such as Vancomycin, metronidazole, Nitroimidazole, Tylosin, and streptomycin are often used and associated with gastrointestinal issues in humans [50].

3.1.5. Mutagenic Effect

Mutagens are substances or chemicals that have the ability to change a DNA molecule's structure, changing a cell's or organism's genetic composition. Alkalizing chemicals and similar DNA bases have been demonstrated in studies to be mutagenic. The human population is becoming increasingly fearful of a potential chromosome break or gene mutagen caused by drugs [51].

3.1.6. Teratogenic Effect

It has been documented that toxic metabolites of medications or chemical agents can cause congenital malformations in the fetus during pregnancy. These medications, also known as teratogens, change the developing embryo's or fetus's anatomical and functional integrity during the crucial stage of gestation. Research has demonstrated that when taken during the early phases of conception or pregnancy, the anthelmintic benzimidazole is extremely harmful to embryos and not just mutagenic but also teratogenic [52].

3.2. Impact on the Global Economy

The administration of antibiotics to livestock at therapeutic or subtherapeutic doses, along with the resulting residues found in food animals, has emerged as a significant global concern. Consumer confidence has been eroded by the growing awareness of the possible risk of diseases like cancer as well as the distortion of the body's functional and system integrity (i.e., endocrine, nervous, reproductive, and immune systems) as a result of consuming such "compromised" food of animal origin [53]. This has negatively affected the global economy. Additionally, the committee of nations does not commonly accept the maximum residual limits (MRLs) set by the Codex Alimentarius Commission (Codex) for veterinary drug residues as an international standard for food safety [54]. Different countries have different standards for food safety since Codex and the World Trade Organization (WTO) are unable to enforce the implementation of MRLs. These disagreements typically result in trade disputes that gradually reduce the amount of meat and meat products exported.

3.3. Impact of Antibiotic Resistance and Ways of Prevention

Global public health has identified the fight against antibiotic resistance as a top concern. A worldwide action plan on antimicrobial resistance was released [24] and it was suggested that each nation create its own plan. Addressing antibiotic resistance is critical to preserving the efficacy of antibiotics as a vital therapeutic resource. The treatment of resistant infections is associated with increased costs due to the necessity for more expensive second-line medications, additional research, and extended hospital stays. Other indirect costs linked to antimicrobial resistance (AMR) include lost production as a result of increased morbidity and death [55]. A well-established approach to addressing antibiotic resistance involves the gradual reduction of using antibiotics as routine feed additives in animal agriculture, thereby mitigating the associated harms. Research indicates that the use of antibiotics in agriculture contributes to the human carriage of resistant organisms, and evidence shows that the prevalence of such carriage significantly decreases when these antibiotics are phased out [56].

Antibiotic residues at high concentrations have been found in milk and meat intended for human consumption. In Ethiopia, the Oxytetracycline level was detected in 70.58% of the farms in Debre Zeit and 83.33% of the farms in Nazareth; likewise, the penicillin G level was identified in 20.58% of the farms in Debre Zeit and 16.16% of the farms in Nazareth, both of which were above the maximum residue limit set by the FAO. In a different investigation on poultry flesh, Oxytetracycline was found in 27.4% of the bird. Additional investigations on Oxytetracycline, penicillin G from milk, and tetracycline from beef were also carried out in Ethiopia [57]. In Bahirdar, Northern Ethiopia, research revealed that tetracycline was used on nearly all 42 beef farms (97.67%). Apart from β-lactams, sulfonamide medications such as Diminazine aceturate and Sulfadimidine 21 (48.84%) and 4 (9.30%), are also included. Of 37 (86.05%) cattle farms, none have a medicine withdrawal period in place, and none have informed their customers about the potential negative effects of antibiotics. Antimicrobial residue positive was found in 191 (76.4%) of the 250 beef cattle that were slaughtered, with a 95% confidence interval of 71.10-81.70%. The origin of the beef farming system did not substantially correlate ($p>0.05$) with the presence of antibiotic residues [58]. Veterinary medications are used in livestock production because they are considered necessary for food safety, disease prevention and treatment, physiological function modification, growth and productivity enhancement, and improvement of physiological functions.

The development of the asymptomatic carrier condition may be more significantly influenced by antibiotic usage in agriculture than in hospitals [59]. To effectively combat rising antimicrobial resistance, it is crucial to pursue the discovery of novel antimicrobial agents and strategies to extend the effective lifespan of existing antibiotics. A comprehensive understanding of the molecular basis of resistance mechanisms is essential in addressing and preventing antibiotic resistance by investigating how bacteria acquire and express resistance, targeted approaches can be developed to enhance the effectiveness and sustainability of current and future antibiotics. Accordingly, using antibiotics prudently from a One Health viewpoint will help to reduce antibiotic resistance and stop the spread of resistance genes [60].

4. Conclusion and Recommendations

Antimicrobials are commonly used to treat and prevent a wide range of bacterial diseases in both humans and animals. In general, the indiscriminate use of antimicrobials in animals can lead to residues in consumables including milk, eggs, and meat. The main causes of the high prevalence of resistant strains are human management practices, such as inappropriate use, including off-label or illegal drug applications, failure to adhere to the withdrawal period and overdosing, use of antibiotics at subtherapeutic levels, and/or short treatment periods. These residues have the potential to cause several adverse effects, including immunopathological reactions, nephropathy (gentamicin), hepatotoxicity, reproductive problems, toxicity to the bone marrow (chloramphenicol), carcinogenicity (sulphamethazine, oxytetracycline, furazolidone), and mutation. Given the current high levels of antimicrobial resistance, establishing permanent resistance surveillance programs at the national level is essential. Therefore, the solution to antimicrobial resistance requires a coordinated regulatory body to monitor the use of antimicrobial drugs to control diseases and also enforce punishment for indiscriminate usage.

Based on the above remarks, the following recommendations need to be considered:

- Ensuring the quality of raw milk, meat, and eggs requires targeted hygiene training for all individuals involved in the dairy and livestock production chain to minimize contamination risks.
- A proper withdrawal period must be observed to reduce the unexpected resistance in foods of animal origin.
- All efforts including education of farm owners about the proper utilization of antimicrobials, side effects of the irrational use of drugs, effective surveillance, monitoring and control on the use of veterinary drugs to prevent drug resistance in foods of animal origin were recommended.
- In order to protect consumers from AMR, food safety management programs should be implemented and highly considered.
- Cooking and freezing procedures are important in the inactivation of antimicrobial resistance, because the heat treatment of animal foodstuffs may inactivate antimicrobials.
- Public awareness should be given on the proper use, handling, and storage of antimicrobials prioritizing field veterinarians, livestock farmers and other drug users (para veterinarians).
- Every country should adopt laws on antibiotic usage in animals and their residue limits in foods.
- There is a need to undertake further studies on the assessment of the global burden of antimicrobial resistance.
- A One Health approach, involving collaboration among specialists from diverse disciplines, is essential for effectively addressing and mitigating the challenges of antimicrobial resistance.

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Contribution of Authors

All the authors contributed equally.

Conflict of Interest

There was no conflict of interest among the authors.

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