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Chapter

Current Situation of *Escherichia coli* Antibiotic Resistance in Food-producing Animals, Wild Animals, Companion Animals, and Birds: One Health Perspectives

Hassan Ishag, Ghada Abdelwahab, Zulaikha Al Hammadi and Asma Abdi

Abstract

*Escherichia coli* (*E. coli*) has shown antimicrobial resistance (AMR) to a range of antibiotics, including the last resort antibiotics, which represent a global burden. Thus, it is essential to consider the AMR from a One Health perspective due to the ability of antimicrobial resistance to be transmitted between animals and humans share the same environment. As a result, and to minimize the emergence and spread of the AMR requires coordination in the multi-sectorial effort. However, in most cases, animals and birds have been ignored by public health authorities while antimicrobial resistance is being reported. This gap poses a serious public health burden due to the close contact between food-producing animals, companion animals, or companion birds, humans, and their environment. Therefore, this chapter aims to highlight the current situation of *E. coli* AMR in food-producing animals, wild animals, companion animals, and birds from One Health perspective. In conclusion, the chapter shows that *E. coli* exerted resistance to a range of antibiosis, including the last resort of antibiotics in livestock and birds worldwide which calls for joint efforts under one health umbrella to address the challenge of *E. coli* AMR in animals and birds.

Keywords: livestock, companion animals, companion birds, antimicrobial resistance, *E. coli*, One Health

1. Introduction

*Escherichia coli* (*E. coli*) is a Gram-negative bacteria belonging to the family of Enterobacteriaceae. The bacteria are ubiquitous and can be isolated from humans, animals, and environments. The *E. coli* was also isolated from companion birds with a prevalence of 30.7% [1] and occasionally from companion animals (dogs and cats) [2]
which represent a new challenge for the One Health Approach. While the bacteria can normally exist as a microflora in the intestine of humans and animals [3], it can be pathogenic causing serious diseases such as diarrhea and hemorrhagic colitis (HC) [4, 5]. The overuse and misuse of antibiotics during treatment of such illnesses caused by *E. coli* in humans or livestock have been linked to the development of antimicrobial-resistant (AMR) or multidrug-resistant (MDR) *E. coli* over time by mutation or horizontal transfer of mobile genetic elements carrying resistance genes [6–15]. This AMR is generally considered a One Health issue affecting animal, human, and environmental health [16, 17] bearing in mind that antibiotic-resistant bacteria, resistance genes, or plasmids can spread by animals, birds, and humans through their shared environment [18, 19]. As a result, more efforts have been conducted to reduce the impact of AMR including the Global Action Plan adopted by WHO to ensure global capacity to control and prevent AMR bacterial infectious diseases [20] and the Global Leaders Group (GLG) on AMR to advocate AMR controlling strategies in different sectors covering human, animal, and environmental [21]. This chapter intended to provide a critical review on current situation of *E. coli* AMR in food-producing animals, companion animals, and companion birds from One Health perspective. This may call for joint efforts to implement new policies, renew research to pursue steps to manage the AMR challenge globally.

2. Current situation of *E. coli* antibiotic resistance in food-producing or wild animals, companion animals, and birds

2.1 *E. coli* AMR in food-producing or wild animals: one health perspective

The *E. coli* isolated from food-producing animals have shown resistance to several antibiotics used for the treatment of these animals. Moreover, food derived from animal sources was found to contain resistant bacteria and resistant genes [7].

Between the periods of 2014 and 2019 in the United Arab Emirates (UAE), about 165 *E. coli* isolates were obtained from livestock samples including (camel [25.5%], sheep [25.5%], goat [32.7%], and poultry [16.4%]). The isolated *E. coli* was found to be multidrug-resistant carrying one or more of the resistance gene/s for the same antibiotic [22]. Specifically, the 165 *E. coli* isolates showed resistance to ampicillin (10 μg), tetracycline (30 μg), co-trimoxazole (25 μg), gentamicin (10 μg), and enrofloxacin (5 μg) by 95.4%, 93.6%, 86%, 85%, and 82.7%, respectively. The predominant resistance genes detected by PCR were blaCMY (72%), blaTEM-1B (96.3%) for ampicillin, tetA (8.8%), tetB (68.3%) for tetracyclines, sul2 (95%), sul3 (84%), dfra1 = (44.5%) for co-trimoxazole, aph(3′)-Ia = (82.1%), aph(6)-Id (98.2%) for aminoglycosides, and aac(6′)-Ib (100%) for enrofloxacin [22].

A study conducted in the United States showed that *E. coli* isolates from livestock were more resistant compared to those from human clinical samples [23]. In Nepal, *E. coli* was isolated from 159 chicken cecum samples and its antibiotic resistance was studied. It has been concluded that 113 (71%) had resistance to ≥3 antimicrobial classes. The highest resistance was observed against tetracycline (86%), followed by ciprofloxacin (66%), ampicillin, and cotrimoxazole. Similar findings were also reported from the South Asia region where more than 70% of the *E. coli* were resistant to streptomycin, enrofloxacin, and sulfonamides, and almost 90% in the case of tetracycline [24].

In Egypt, a study of Enteropathogenic *E. coli* (EPEC) either isolated from diarrhoeic calves (17/75), milk (8/150), or workers (3/15) in dairy farms has reported that
all EPEC (100%) isolates were MDR, with high resistance rates observed in ampicillin (100%), tetracycline (89.3%), cefazolin (71%), and ciprofloxacin (64.3%) [25].

In China, 89.20% of tested E. coli isolates from chicken fecal samples showed multi-drug resistance against several antibiotics. Moreover, the antibiogram profile of E. coli isolates from broiler chickens in Chitwan, Nepal also showed multi-drug resistance (94%) with the highest resistance for ampicillin (98%) [26].

In Bangladesh and China, E. coli isolates from poultry samples reported high resistance against ampicillin and tetracycline [27, 28]. Similarly, in Pakistan, E. coli isolated from different chicken samples including meat, chicken fecal, and respiratory secretions showed more resistance to co-trimoxazole, chloramphenicol, and moxifloxacin compared to other antibiotics [29]. In contrast, European data from the Netherlands, France, and the UK showed moderate resistance to tetracycline, streptomycin, ampicillin, and sulfonamides with very low resistance phenotypes determined in Sweden [30].

In Southwestern Uganda, a study about E. coli AMR was conducted between January 2018 and March 2019. The results showed that among 84 E. coli isolates from cattle, fecal swab showed high resistance to cefazolin, ampicillin, and amoxicillin-clavulanic acid by 96%, 80%, and 67%, respectively. Low resistance was reported in ciprofloxacin, levofloxacin, and imipenem. Interestingly, all E. coli isolates were sensitive to gentamicin [31]. Similarly, low rates of antimicrobial resistance of E. coli isolated from dairy cattle to gentamicin (0.89%) were also reported in Zambia [32] and less than 10% resistance to gentamicin from cattle dairy farms in Jordan [33]. On the other hand, higher antimicrobial resistance to gentamicin was previously reported from the E. coli isolated from milk in Bengal, India [34]. The varied prevalence of resistance patterns against gentamicin from different regions globally could be explained by the differences in the patterns of antibiotics used in these regions.

In the same study from Southwestern Uganda, antimicrobial resistance against cefazolin, ampicillin, cotrimoxazole, and amoxicillin–clavulanic acid was reported as high among the E. coli isolates from humans (n = 133) by 98%, 85%, 72%, and 60%, respectively. However, gentamicin, ciprofloxacin, levofloxacin, and imipenem showed low antimicrobial resistance patterns at 2%, 5%, 5%, and 5%, respectively. Also noted from this study, there was no statistically significant difference in the resistance to a particular antibiotic except for the co-trimoxazole in human and animal isolates of E. coli indicating a possibility of a cross-transmission [31].

In Africa and other countries as well, high resistance to cephalosporins among E. coli isolated from cattle has been reported [34–36]. Moreover, ampicillin and amoxicillin resistance were also reported in several studies [34–37].

To understand the molecular mechanisms behind E. coli resistance, several studies have been conducted. In the middle East, studies from Egypt have detected the TEM, SHV, CTX-M-9, CTX-M-15, and OXA-7-producing E. coli strains in broiler farms. The plasmid-mediated AmpC beta-lactamase genes blaCMY-2, and blaDHA-1 were also observed. Furthermore, studies performed on poultry hatcheries revealed similar results where blaTEM, followed by blaSHV, blaMOX-like, blaCIT-like, and blaFOX were the most common beta-lactamase genes detected [38]. However, blaCTX-M (including CTX-M-1, CTX-M-9) and SHV-12 were the only ESBL types detected in E. coli strains isolated in Chicken in Palestine [39]. In Lebanon, a study conducted in chicken farms found several ESBL and AmpC-producing Gram-negative bacilli (GNB). These included mainly blaCTX-M, blaTEM, and blaCMY genes [40]. On contrary, the presence of CTX-M-15-producing E. coli in Lebanese cattle was reported [41]. In Turkey, CTX-M-15 was detected in E. coli strains belonging to the
B1 phylogenetic group isolated from cattle with bovine mastitis [42] and was also reported in Egyptian poultry with other β-lactamase-encoding genes such as bla-TEM-104, blaCMY2, and blaOXA-30 in *E. coli* strains including the sequence type ST131 [39].

In the Gulf region, particularly in the KSA, blaSHV and blaTEM were reported in *E. coli* strains isolated from poultry. Furthermore, in Iran *E. coli* strains producing blaSHV were isolated from raw milk and dairy products across the country [38].

Multidrug-resistant *E. coli* O25b:H4 ST131 was observed worldwide in humans, companion animals, and livestock [43]. Many farmers in Egypt tend to use cefotaxime injections (a third generation cephalosporin banned in poultry) to treat diseases in chicken (such as colibacillosis) while treatment with fluoroquinolones and aminoglycosides is failed [44].

From One Health perspective, both in cattle and poultry, MLST analysis revealed a high variety of sequence types in isolated *E. coli* strains. Some of these sequence types were shown to be common to animals as well as to humans (ST10, ST617, ST58, ST69, ST155, and ST156) [40, 41]. This emphasizes the role of livestock in the dissemination of MDROs in the One Health concept.

Unlike ESBL and AmpC producers, carbapenemase-producing GNB are not widely spread in animals in the Middle East. Isolation of ST38 *E. coli* positive for the blaOXA-48 from fowl was reported in Lebanon and, OXA-48 and OXA-181-producing *E. coli* were detected in Egypt [38].

Colistin as a “last resort” antibiotic, is used for the treatment of severe infections caused by multidrug-resistant Gram-negative bacteria. The worldwide spreading of mobile colistin resistance genes (mcr) in environments is a major obstacle to combat antimicrobial resistance. Lebanon is considered one of the more recent countries in which colistin resistance has emerged. Dandachi *et al.* (2018c) reported the first detection of ESBL/mcr-1 ST515 *E. coli* strain isolated from chicken in the South of Lebanon [40].

In Egypt, colistin is used in animal husbandry in farms, calves, poultry, and rabbits [45]. Colistin-resistant avian isolates of *E. coli* that have been found in Egyptian farms imply that the overuse of colistin in the farming industry can indeed augment the emergence of colistin resistance in Egypt [45]. Indeed, mcr-1 gene was detected in samples collected from both poultry and cattle [45, 46]. In cattle, mcr-1 was harbored by an ST10 *E. coli* strain [46]. In the light of the One Health concept, those resistant strains can potentially enter the human food chain and result in treatment-challenging infections that pose a serious health threat calls for the integration of One Health approach to combat antibiotic resistance.

One notable finding study in Denmark and Poland where mcr-1 was detected in one *E. coli* isolates classified as wild type (susceptible; colistin MIC of 2 mg/L) [47]. Preliminary results from other studies revealed similar findings of *E. coli* isolates, particularly from poultry, with MIC of 2 mg/L and carrying the mcr-1 gene [47].

A study in Brazil between April 2015 and June 2016 from broiler chicken and free-range layer hens (n = 107 *E. coli* isolates) revealed that mcr-1 gene was detected in 62 (57.9%) isolates and the mcr-5 gene was detected in 3 (2.8%) isolates mcr-2, mcr-3, mcr-4, mcr-6, mcr-7, mcr-8, and mcr-9 were not detected in any isolate. Moreover, agar dilution assay revealed that the mcr 1 and 5 positive isolates were phenotypically resistant to colistin [48].

Sonnevend *et al.* investigating MCR-producing Enterobacterales of animal origin from fecal samples of poultry collected in four farms in the United Arab Emirates. The study revealed that mcr-1 positive strains were identified in 36 of the 40 samples
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(90%) [49]. Thirty-four multi-drug resistant \( E. \) coli of 16 different sequence types, two \( Escherichia \) \( \text{albertii} \), two \( Klebsiella \) pneumoniae, and one \( Salmonella \) minnesota were identified [49]. Beyond various aminoglycoside, tetracycline, and cotrimoxazole resistance genes, seven of them also carried ESBL genes and one blaCMY-2. Six IncHI2, 26 IncI2, and 4 IncX4 MCR-plasmids were mobilized. In the case of the IncHI2 plasmids co-transferring ampicillin, chloramphenicol, and tetracycline resistance. The author commented that the diversity of mcr-1 positive strains suggest a complex local epidemiology calling for coordinated surveillance including animals, retail meat, and clinical cases [49].

Another study in Qatar also investigated the presence of mcr-1 in fecal samples collected from one live bird market and two broiler chicken farms. Using Etest method, it has been found that 15.5% of the isolates were resistant to colistin mcr-1 [50]. Reports of mcr-associated resistance in \( E. \) coli of poultry appear to be relatively limited, but its prevalence requires assessment since poultry is one of the most important and cheapest sources of the world’s protein and the emergence of resistance could limit our ability to treat disease outbreaks.

On the other hand, wild animals not normally exposed to antimicrobial agents can acquire antimicrobial agent-resistant bacteria through contact with humans and domestic animals and through the environment. Examples of the worldwide distribution of antibiotic-resistance genes and in \( E. \) coli isolates from animals and humans was summarized in Table 1.

2.1.1 Evidence of \( E. \) coli AMR genes or plasmids spread by food-producing animals and humans through their shared environment

In one study the frequency of AMR in \( E. \) coli isolated from wild small mammals (mice, voles, and shrews) living in farms and those isolated from natural area was assessed [51]. The frequency was also compared between \( E. \) coli isolated from swine and those isolated from wild small mammals living on the same farm. It has been found that \( E. \) coli isolates from wild small mammals living on farms have higher rates of tetracycline resistance compared to \( E. \) coli isolates from environments, such as natural areas. Resistance to tetracycline was also observed in isolates recovered from swine (83%) [51].

2.2 \( E. \) coli AMR in companion animals (dogs and cats): one health perspectives

Most of the AMR data were focused on food-producing animals and few in companion animals [16]. As reported above, the gap in the overall AMR situation could pose serious problems for public health due to the close contact between owners and companion animals that are considered an important potential source of AMR [52]. However, few studies on these animals were conducted by different research groups [1, 53–55]. For example, in Europe, in Denmark: \( E. \) coli AMR in cats and dogs was observed against amoxicillin–clavulanic acid, fluoroquinolones group, aminopenicillins group, sulfamethoxazole–trimethoprim, and third-generation cephalosporins [56]. In France, the results of the latest report showed a high AMR level of amoxicillin and amoxicillin–clavulanic acid in \( E. \) coli isolates [57]. In Germany, it was found that 100% \( E. \) coli strains isolated from urinary tract infections in cats were resistant to amoxicillin–clavulanic acid, whereas for dogs the resistance was below 20% [58]. In Norway, the highest AMR level in \( E. \) coli isolates was aminopenicillins [56]. In Sweden, the AMR prevalence in \( E. \) coli isolated from dogs and cats are ampicillin,
<table>
<thead>
<tr>
<th>Country</th>
<th>Animal/source</th>
<th>Antibiotic</th>
<th>Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Arab Emirates</td>
<td>Camel = 42/165 (25.5%), sheep = 42/165 (25.5%), goat 54/165 (32.7%), and poultry</td>
<td>Ampicillin (10 μg), tetracycline (30 μg), co-trimoxazole (25 μg), gentamicin (10 μg), and enrofloxacin (5 μg)</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>Chicken</td>
<td>Tetracycline (86%), followed by ciprofloxacin (66%), ampicillin, and cotrimoxazole</td>
<td></td>
</tr>
<tr>
<td>Egypt</td>
<td>Diarrhoeic calves (17/75), milk (8/150), or workers (3/15) in dairy farms</td>
<td>Ampicillin (100%), tetracycline (89.3%), cefazolin (77%), and ciprofloxacin (64.3%)</td>
<td></td>
</tr>
<tr>
<td>Bangladesh and China</td>
<td>Chicken</td>
<td>Ampicillin and tetracycline</td>
<td></td>
</tr>
<tr>
<td>Chitwan, Nepal,</td>
<td>Chicken</td>
<td>Multi-drug resistant (94%) with highest resistance reported for ampicillin (98%)</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>Chicken</td>
<td>Co-trimoxazole, chloramphenicol, and moxifloxacin</td>
<td></td>
</tr>
<tr>
<td>Netherlands, France, and Sweden (Europe)</td>
<td>Chicken</td>
<td>Moderate resistance to tetracycline, streptomycin, ampicillin, and sulfonamides, with very low resistance phenotype determined in Sweden</td>
<td>Sensitive to gentamicin</td>
</tr>
<tr>
<td>South-western Uganda</td>
<td>Cattle</td>
<td>High resistance to cefazolin, ampicillin, and amoxicillin-clavulanic acid by 96%, 80%, and 67%, respectively. Low resistance was reported in ciprofloxacin levofloxacin and imipenem</td>
<td>Low resistance to gentamicin, ciprofloxacin, levofloxacin, and imipenem by 2%, 5%, 5% and 5%, respectively</td>
</tr>
<tr>
<td>South-western Uganda</td>
<td>Humans</td>
<td>High resistance against cefazolin, ampicillin, cotrimoxazole, and amoxicillin-clavulanic</td>
<td></td>
</tr>
<tr>
<td>Zambia</td>
<td>Cattle</td>
<td>Low rates of resistance (0.89%) to gentamicin</td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>Cattle</td>
<td>Less than 10% resistant to gentamicin</td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>Cattle</td>
<td>High resistance to cephalosporins and ampicillin</td>
<td></td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Country</th>
<th>Animal/source</th>
<th>Antibiotic</th>
<th>Sensitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companion animals (dogs and cats)</td>
<td>Denmark</td>
<td>Dog and cat Amoxicillin–clavulanic acid, fluoroquinolones group, aminopenicillins group, sulfamethoxazole–trimethoprim, and third-generation cephalosporins</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>Cats and dogs</td>
<td>Amoxicillin and amoxicillin–clavulanic acid</td>
<td></td>
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<tr>
<td>Germany</td>
<td>Cats and dogs</td>
<td>100% <em>E. coli</em> strains isolated from urinary tract infections in cats were resistant to amoxicillin–clavulanic acid, whereas for dogs the resistance were below 20%</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>Cats and dogs</td>
<td>Aminopenicillins</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Cats and dogs</td>
<td>Ampicillin, cephalexin, cefotaxime, gentamicin, tetracycline, sulfamethoxazole–trimethoprim, and enrofloxacin</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td></td>
<td>Cephalothin</td>
<td></td>
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</tbody>
</table>

*Note: References are cited in the main text.*

**Table 1.**

Examples of the worldwide distribution of antibiotic resistance and sensitive ones in *E. coli* isolates from animals and humans.
cephalaxin, cefotaxime, gentamicin, tetracycline, sulfamethoxazole–trimethoprim, and enrofloxacin [56]. In Switzerland, in *E. coli*, higher AMR to cephalothin was observed in dogs and cats [56, 59]. Examples of antibiotic resistance in *E. coli* were summarized in Table 2.

### 2.3 *E. coli* AMR in companion and wild birds: one health perspectives

In pet bird farms, the administration of antibiotics without control is a common practice, which contributes to the increasing resistance rates. Water contact and acquisition via food seem to be major aspects of the transmission of resistant bacteria of human or veterinary origin to wild birds or wild animals [60]. Wild birds or wild animals, in general could therefore serve as reservoirs of resistant bacteria and genetic determinants of antimicrobial resistance [60], which could be transferred directly or indirectly to humans and animals. From One Health perspective, this risk should not be underestimated. However, information on the *E. coli* AMR in birds is scarce. Wild birds, specifically in prey, waterfowl, and passerines birds, were found to act as a reservoir of multi-drug resistant *E. coli* strains, which represents a risk for human and

<table>
<thead>
<tr>
<th>Country</th>
<th>Animal/source</th>
<th>Resistance gene</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Arab Emirates</td>
<td>Camel = 42/165 (25.5%), sheep = 42/165 (25.5%), goat = 54/165 (32.7%), and poultry</td>
<td>blaCMY = 119/160 (72%), blaTEM = 154/160 (96.3%) for ampicillin, tetA = 162/164 (98.8%), tetB = 112/164 (68.3%) for tetracyclines, sul2 = 156/164 (99%), sul3 = 138/164 (84%), dfra17 = 74/164 (44.5%) for co-trimoxazole, aph(3’)-Ia = 134/164 (82.1%), aph(6)-Id = 161/164 (98.2%) for aminoglycosides, and aceF(6)-Ib = 61/61 (100%) for enrofloxacin</td>
</tr>
<tr>
<td>Middle East, studies from Egypt</td>
<td>Poultry</td>
<td>TEM, SHV, CTX-M-9, CTX-M-15, and OXA-7, blaCMY-2 and blaDHA-1, blaTEM, followed by blaSHV, blaMOX-like, blaCIT-like, and blaFOX.</td>
</tr>
<tr>
<td>Palestine</td>
<td>Chicken</td>
<td>blaCTX-M (including CTX-M-1, CTX-M-9) and SHV-12 (ESBL type)</td>
</tr>
<tr>
<td>Lebanon</td>
<td>Chicken</td>
<td>blaCTX-M, blaTEM, and blaCMY gene</td>
</tr>
<tr>
<td>Lebanon</td>
<td>Cattle</td>
<td>CTX-M-15</td>
</tr>
<tr>
<td>Turkey</td>
<td>Cattle</td>
<td>CTX-M-15</td>
</tr>
<tr>
<td>Egyptian</td>
<td>Poultry</td>
<td>CTX-M-15 and as blaTEM-104, blaCMY2, and blaOXA-30</td>
</tr>
<tr>
<td>Gulf region, particularly in the KSA</td>
<td>Poultry</td>
<td>blasHV and blaTEM</td>
</tr>
<tr>
<td>Iran</td>
<td>Cattle</td>
<td>blasHV</td>
</tr>
<tr>
<td>Lebanon</td>
<td>Poultry</td>
<td>mcr</td>
</tr>
<tr>
<td>Egypt</td>
<td>Poultry and cattle</td>
<td>mcr-1</td>
</tr>
<tr>
<td>Denmark and Poland</td>
<td>Poultry</td>
<td>mcr-1</td>
</tr>
<tr>
<td>Brazil</td>
<td>Poultry</td>
<td>mcr-1 and mcr-5</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>Poultry</td>
<td>mcr</td>
</tr>
</tbody>
</table>

*Note: References are cited in the main text.*
animal health by spreading these resistant bacteria to waterways and other environments through their fecal deposits [61, 62]. In one study, it has been reported that domestic canaries, show multi-drug resistance, especially against amoxicillin, spiramycin, erythromycin, tiamulin, and tylosin [63]. Ghanbarpour et al. [64] characterized the AMR genotypes in pigeons. Approximately half of the E. coli isolates were found to be resistant to three or more antibiotics (40.1%), particularly to tetracycline, cefotaxime, kanamycin, trimethoprim–sulfamethoxazole (28.2%, enrofloxacin), gentamicin, and florfenicol (7.8%) by 98%, 49.3%, 34.2%, 28.0%, 17.1%, 11.1%, and 7.8%, respectively [64]. Domestic pigeons are likely to carry antibiotic-resistant genes that could transfer directly or indirectly to humans and animals. Starlings species were also examined for E. coli AMR and were showed the highest prevalence of AMR (5.4%), with streptomycin and tetracycline as predominant resistant phenotypes [65].

Furthermore, 265 cloacal swab samples were collected from healthy companion birds (parakeets, 116), 59 canaries (59), parrots (56), 30 Indian nightingales (30), 3 finches, and 1 Golden finch. Out of these samples, E. coli was isolated from 37.7% of samples and the bacteria was tested for its susceptibilities against 16 antimicrobials. Most of the isolates were resistant to tetracycline followed by sulfamethoxazole/trimethoprim, streptomycin, and kanamycin by 84%, 46%, 34%, and 25%, respectively. Eleven parakeet and two parrot E. coli isolates were found to be resistant to all quinolone classes of antimicrobial agents, and three parakeet E. coli isolates showed resistance to all aminoglycosides. Additionally, 67% of the isolates showed multi-drug resistance. Of note, these commensal E. coli strains may carry antimicrobial resistance determinants, and act as reservoirs of the resistance, which transfer these resistance determinants to the pathogenic bacteria. As the wild birds are not directly exposed to antibiotics, contact with sewage or animal manure may play a role in the acquisition of resistance genes and especially migratory birds which contribute to their pandemic spread. This highlights the need for continuing efforts to examine the potential role of animals in agricultural habitats as vectors of antimicrobial resistance in the environment.

3. Conclusion

The chapter reflects wide uncontrolled and overuse of antimicrobials, easy availability of antimicrobials in many countries, and lack of awareness about AMR were major issues contributing to AMR in humans, animals, and birds. The high prevalence of resistance among E. coli in animals and birds worldwide calls for rational use of antimicrobials, AMR education, and awareness programs, implementation of antimicrobial stewardship in the veterinary field, and multi-sectorial coordination for fitting the spread of AMR.

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Conflict of interest

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