Egypt. J. Vet. Sci., pp. 1-15

Egyptian Journal of Veterinary Sciences

https://ejvs.journals.ekb.eg/

Exploring the Interconnectedness of *E. coli* Antimicrobial Resistance in Poultry, Human Health, and Environmental Factors in Bangladesh: A Review

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Abstract

ESCHERICHIA coli (*E. coli*) incidence and antimicrobial resistance patterns in poultry farms across Bangladesh appear to be a multifaceted challenge with significant implications for poultry, human health, and environmental integrity. A review and search were conducted to analyze the studies reporting on the prevalence rates, responsible isolates, and resistance patterns to frequently applied antibiotics of E. coli in the poultry industry in Bangladesh. Relevant literature was sourced from different databases. A total of 95 studies were considered to meet the inclusion criteria, comprising data from commercial and backyard poultry farms. This review synthesizes the prevalence of E. coli infection ranges from 34 – 100 % in broilers, 56 – 80 % in layers, and 58 – 78 % in overall poultry observed in different research. It was also found that antibiotic sensitivity to E. coli is decreasing day by day. On the contrary, the resistance gene is increasing in poultry, thus E. coli resistance is found at higher levels. A notable correlation between Antimicrobial Resistance (AMR) patterns observed in poultry and those remarked in human clinical isolates highlights the potential for transmission to humans through direct exposure or ingesting contaminated products. This Antimicrobial Resistance (AMR) poses a serious threat to human health, along with the environment and other living beings. Addressing these challenges requires a coordinated effort to involve policymakers, researchers, healthcare professionals, and relevant livestock experts. Therefore, strategies should focus on promoting responsible antibiotic use in poultry, enhancing biosecurity measures, and implementing robust surveillance programs.

Keywords: AMR, Bangladesh, *E. coli*, MDR, poultry, public health.

Introduction

Bangladesh is a developing country with a rich agricultural heritage. Most of the Bangladeshi people are involved in livestock rearing. About 50 % of people are directly employed and 20 % of people are indirectly employed in the livestock sector in Bangladesh [1]. As poultry farming is a profitable agribusiness globally, livestock and poultry contribute approximately 1.47 % to the national GDP of Bangladesh [2]. Bangladesh Rural Advancement Committee (BRAC), revealed in its 2010 yearly report that more than 70% of rural families maintain poultry especially chickens [3]. The poultry industries in Bangladesh have a promising future, and the main poultry products include chicken, duck, quail, pigeon, and turkey. There are four major varieties of chickens such as Broiler, Layer, Sonali and Indigenous/Native. In Bangladesh, the broiler breeds represented more than 58.39 % of the chicken population in 2019, with more than 53,000 broiler farms operating across that year [4]. Sonali chickens accounted for 28% of the chickens in the country in the same year. Additionally, more than 8.23 % of all chickens were laying hens [4]. There were 90,000 registered chicken farms in 2020 [5]. However, these uplifting industries are threatened by various microbial infections. *Escherichia coli* are the common poultry pathogens that cause a range of

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(Received 13 May 2025, accepted 12 June 2025)
DOI: 10.21608/ejvs.2025.384337.2841

diseases in poultry and have a great economic impact on the poultry farming sub-sector in Bangladesh. *E. coli* causes colibacillosis in poultry, resulting in extra-intestinal disruptions including air-vasculitis, pericarditis, peritonitis, salpingitis, synovitis, osteomyelitis, and yolk sac infections [6]. Colibacillosis leads to significant economic losses in the poultry industry due to increased mortality rates and reduced production efficiency in the affected poultry [7]. *E. coli* has zoonotic potential [8] linked to a major public health concern [9]. Antimicrobial drugs, especially antibiotics, are frequently utilized for both prophylaxis and prevention of the outbreak of those poultry diseases. Antimicrobial usage in poultry (hens) in Asia is expected to increase by 129 % by 2030 [10]. The indiscriminate application of antibiotics in the poultry industry may have contributed to *E. coli* drug resistance. Antimicrobial Resistance (AMR) has been extensively studied in humans, cattle, and poultry products. This global health concern emerges as organisms evolve and develop resistance to drugs, resulting in infections that are increasingly difficult to treat [11]. It is estimated that Antimicrobial Resistance (AMR) accounts for 10 million global population deaths in the next 35 years [12]. Drug-resistant *E. coli* bacteria can infiltrate the food supply from production to consumption via eggs, meat, and other pollutants, posing a significant risk to consumer health. The unregulated proliferation of Antimicrobial Resistance (AMR) poses the most contentious problem to human health, animal welfare, and ecosystems in the twenty-first century [13]. The pervasive utilization of AMR has emerged as a significant impediment to economic advancement [14]. The presence of multidrug-resistant *E. coli* in poultry poses significant public health concerns. A significant number of multidrug-resistant (MDR) *E. coli* have zoonotic potential, indicating their capacity to transmit to humans and affect various elements of the 'One Health' framework. Moreover, some AMR determinants can be transmitted to other human bacterial pathogens through transferable genetic elements. This review focuses on the prevalence, distribution, and patterns of Antimicrobial Resistance (AMR) in *E. coli* in poultry, their correlation with food animals, humans, and the environment, as well as strategies for preventing and controlling outbreaks of these infections in poultry. The aim is to enhance understanding of the implementation of effective intervention strategies and improved management practices to mitigate Antimicrobial Resistance (AMR)-related risks associated with poultry in Bangladesh.

Material and Methods

A systematic literature review was conducted to identify all published publications demonstrating the prevalence of mostly *E. coli* and the utilization and resistance patterns of various antibiotics in Bangladesh. Relevant studies published between 2000 and 2024 were sourced from Google Scholar, PubMed, Science Direct, Research Gate, and Bangladeshi online journal platforms, including Bangladesh Journals Online. Modifications were implemented to satisfy search engine standards, and advanced search parameters were utilized for querying Google Scholar. Relevant data were incorporated, while other research was omitted from the literature study.

Results

Involvement of E. coli in the outbreak of Colibacillosis in Poultry

Colibacillosis is caused by an infection with a strain of *E. coli*, as noted by [15]. The symptoms associated with colibacillosis may differ and might result in acute lethal septicemia, air-vasculitis, pericarditis, perihepatitis, peritonitis, and lymphocytic depletion of the bursa and thymus. According to the research by [8], specific strains of *E. coli* may cause colibacillosis. This prevalent disease adversely affects poultry and is characterized by the infection of many organs, including the liver, kidneys, and spleen. Colibacillosis presents a significant challenge for poultry breeders.

Prevalence of E. coli in Poultry

Table 1 illustrates the prevalence of *E. coli* in poultry. The study of [16] indicated an overall frequency of 62.5 % (25/40) in Bangladesh. In the study of [17], they reported that the prevalence of *E. coli* in the fecal sample was 60.0% (n=66/110). The research revealed a 63.6 % (35/55) prevalence of *E. coli* in broilers and 56.4 % (31/55) in layers. The study of [18] reported that around 58 % (145/250) of the overall samples tested positive for *E. coli*, with incidence rates of 42 % (21/50) from egg surfaces, 66 % (33/50) from cloacal swabs, and 82 % (41/50) from feces. A study by [19] identified 101 pathogenic *E. coli* strains (36.20 %) from a total of 279 deceased or ailing broilers and layer hens of various ages suffering from colibacillosis illnesses. Various studies by [20, 21] indicated that the prevalence of *E. coli* in broiler chicken was approximately 82 % and 100 %, respectively. Studies by [22, 23] reported that the prevalence of *E. coli* in layers in Bangladesh is approximately 80 % and 85 %, respectively. The study of [24] reported a 100 % isolation rate of *E. coli* in broilers, while [25] found an overall prevalence of 61.67 % in broilers in Bangladesh. The incidence of *E. coli* in broiler chicken samples was reported to be 44.67% in Dhaka city of Bangladesh [26]. A study by [8] examined 99 samples obtained from layer farms and found that 82 samples (82.83 %) tested positive for *E. coli*, as identified by PCR targeting the *E. coli* 16S rRNA gene. Feces demonstrated the highest incidence at 100 %, whereas air samples exhibited the lowest at 67.74 %. The study by [27] reported that out of 150 cloacal samples from broilers, 89 (59.3 %) tested positive for *E. coli*. Conversely, approximately 38 % of agricultural ambient samples tested positive for *E. coli*. Authors [28] conducted a study in the Gazipur and Mymensingh districts, reporting an overall prevalence of *E. coli* of 76 % in broilers, with district-specific prevalence of 78.7 % in Gazipur and 73.3 % in Mymensingh, respectively. Cloacal swab samples exhibited the highest incidence of *E. coli* at 86 %, whereas hand-washed water samples demonstrated the lowest prevalence at 66 %. A study by [29] indicated that the prevalence of *E. coli* in frozen broiler meat from Dhaka stores was 31.25 %. Authors [30] reported a 78 % prevalence of *E. coli* in poultry. The study of [31] reported in their review study that the total prevalence of *E. coli* isolates from both poultry and their surrounding habitats was 69.3 %. The prevalence of *E. coli* in broilers ranged from 24.3 % to 100 %, with the lowest observed frequency in layers at 61.3 % and the highest at 82.8 %.

A study by [32] reported that *E. coli* isolates were identified in 229 out of 405 broiler meat samples, resulting in a prevalence of 56.5 %. Table 1 data indicates a significant prevalence of sickness caused by *E. coli* infection, posing a concern for farmers, businesspeople, and policymakers in Bangladesh. The prevalence of *E. coli* in various broilers, layers, and other poultry breeds results in significant mortality and financial losses for poultry farmers in Bangladesh.

Sources of E. coli infection and the pathway of transmission

The research of [33] asserts that poultry were perpetually exposed to *E. coli* via feces, water, dust, and their surroundings, as *E. coli* were continually found in the birds' gastrointestinal tracts and extensively disseminated in their excrement. It may re-enter the ecosystem via the excrement of sick avian. Strains of *E. coli* were identified as causative agents of several diseases frequently located in both the intestines and the adjacent environment of hens, as described by [34]. The research study of [31] suggested that oral-fecal transmission may occur between both conspecific and heterospecific poultry species. Poultry were especially vulnerable to *E. coli* illnesses, such as colibacillosis, through the inhalation of contaminated dust. The study of [31] indicated that *E. coli* may be disseminated to new settings by several vectors, including darkling beetles, flies, insects, mites, rats, and wild birds. *E. coli* transmission may occur both horizontally and vertically, either directly, indirectly, or through a combination of both methods. Vertical transmission of *E. coli* may occur when a breeder harbors harmful organisms in their reproductive system and subsequently transmits them to their progeny. Unhygienic management, fecal transfer, and both vertical and horizontal transmission were the primary modes of transmission of this pathogenic bacterium in poultry. The various transmission pathways of *E. coli* must be acknowledged due to their detrimental impact on public health.

Commonly Used Antibiotics in Poultry

In Bangladesh, varieties of antimicrobial agents, including ciprofloxacin, streptomycin, gentamicin, erythromycin, tetracycline, and sometimes furazolidone combined with other antibiotics were authorized and available for treating *E. coli* infections in broilers and layers. According to [35], most of the farmers (215 out of 260) selected antibiotics without any prescription and continuously utilized them as growth promoters and for disease prevention. The compounds that were most frequently utilized were tetracycline, doxycycline, ampicillin, colistin sulfate, nalidixic acid, neomycin, ciprofloxacin, and sulfonamides with trimethoprim. Antibiotics could be readily obtained without showing prescription from physicians and veterinarians. In the private sector, the application of antibiotics was consistent and unregulated where between 50 % and 90 % of medications and drug purchases were conducted without any prescription reported by [35]. A survey was conducted with a formulated questionnaire in Mymensingh district where they considered 120 small-scale layer farms and observed that Ciprofloxacin (22.5 %) was the most commonly used antibiotic on the assessed farms, in addition to enrofloxacin (17.5 %), amoxicillin (16.66 %), oxytetracycline (10.83 %), sulfa medicines (3.33 %), and norfloxacin (1.66 %). Fluoroquinolones were the most common antibiotic class with tetracyclines, aminopenicillin, and polymyxin [36, 37, 38, 39]. The application and treatment with antibiotics were more prevalent in layer farms than in broiler and Sonali farms. Cross-sectional or observation-based research was undertaken on 57 commercial layers and 83 broiler farms in the Chattogram district of Bangladesh to evaluate the use of antibiotics. They stated that Ciprofloxacin was the most widely used antibiotic in layer farms (37.0 %), followed by 33.3 % amoxicillin and 31.5 % tiamulin, whereas 56.6 % colistin, 50.6 % doxycycline, and 38.6 % neomycin were most often used as a medication in broilers [40]. In the study of [41], they mentioned that commercial poultry, especially poultry enterprises employed a range of antibiotic classes such as tetracyclines, fluoroquinolones, macrolides, aminoglycosides, penicillins, and polymyxins. Although Doxycycline, oxytetracycline, and ciprofloxacin were the most frequently observed and documented antibiotics in broilers and layers, the use of amoxicillin was more frequently recorded in Sonali. The farmer had little knowledge of the use of antimicrobial drugs. As a result, they used antibiotics indiscriminately without knowing their function and mode of action. Most poultry farmers followed the guidelines of the dealers and pharmacists, and they suggested different types of antibiotics in single and combination forms. For this reason, farmers used a lot of antibiotics in a single day until their birds got round of disease.

Purpose of Antimicrobial Usage

In the study of [19], they stated that antibiotics were the foremost strategy in reducing the prevalence and mortality rates linked to avian colibacillosis. They also reported that over 95 companies in Bangladesh are involved in poultry animal feed production and incorporate additives like flavomycin, zinc bacitracin, tetracycline, gentamicin, streptomycin, and trimethoprim-sulfamethoxazole in poultry feed. The majority of the farmers frequently administered broad-spectrum antibiotics for promoting growth and disease prevention, particularly tetracycline, ampicillin, nalidixic acid, gentamicin, ciprofloxacin, and trimethoprim. Farmers who applied antibiotics to boost poultry growth believed that the expenses of the drugs were offset by the birds' rapid growth [42]. Few farmers extensively utilized antibiotics for growth enhancement and prevention as a risk-mitigating strategy [43]. Another research study conducted in Bangladesh on small-scale layer farms in the Mymensingh region revealed that nearly 94 % of farmers were using antibiotics without observing the required withdrawal timeframe before commercialization. Approximately 20 % of farmers received antibiotics regularly without any cause. However, 18.34 % of farmers used antibiotics of their choosing based on experience, as antibiotics were easily purchasable from pharmacies and dealer shops [44]. Farmers also believed that using more or various kinds of antibiotics kept their farms safer and more productive [45]. A separate study indicated comparable results, showing that 100% of broiler farms utilized at least one antibiotic throughout the production period, and 32% employed antibiotics for prophylactic purposes [45]. Many farmers were exposed to using antibiotics for weight gain. In an investigation into commercial poultry farming in Bangladesh, it was observed that (23 – 32 %) of farmers used antibiotics as prophylaxis, whereas (8 %) used growth enhancers [45, 46]. About 40.83 % of farmers administered antibiotics for medicinal and preventive as mentioned by [39]. According to on-site assessment and interviews, every commercial poultry producer utilized antibiotics in the course of the poultry production cycle whereas 84.7 % of farmers used antimicrobials prophylactically and only 15.3 % of farmers used them strictly for therapeutic purposes [40]. Ciprofloxacin and doxycycline were the most prevalent antibiotics observed along with tylosin and doxycycline (combination), oxytetracycline, enrofloxacin, and erythromycin, while several others included colistin sulfate. The same farm was treated with several antibiotics [47]. A cross-sectional study was conducted by [40] in Bangladesh, where they found that about 98 % of commercial poultry farms applied antimicrobials in their recent production cycle while 85 % of farmers used antimicrobials for prophylactic purposes. Additionally, [41] stated that over 90 % of commercial poultry farmers administered antibiotics for 3 – 7 consecutive days in their flocks. Based on the farmers' response broiler farms (55 %), layer farms (42 %), and 21 % of Sonali chicken farms utilized antibiotics prophylactically on the first day of the batch production period. Several farmers (16 – 41 %) mentioned that they utilize antibiotics for enhancing poultry growth. Moreover, two-thirds of the farms (66 – 67 % based on the type of production) fostered antibiotics for both therapeutic and prophylactic purposes. They also reported that the percentage of farms that employed antibiotics prophylactically rather than therapeutically was somewhat greater in layer (14 %) compared to broiler (8 %) and Sonali (3 %) farms. In Poultry, antibiotics were used as growth promoters, for preventive and treatment purposes. Multi-type antibiotics and indiscriminate use of those antimicrobials would be the major challenges for the poultry industry of Bangladesh.

Antimicrobial sensitivity and resistance profiles of E. coli

The sensitivity profiles of different antimicrobial drugs are shown in Table 2. Research by [17] mentioned that 91.43 % of broiler isolates exhibited moderate sensitivity to cephalexin, 77.74 % to ciprofloxacin, and 85.71 % to kanamycin. Conversely, 54.28 % of isolates had high sensitivity to chloramphenicol, while 45.71 % demonstrated moderate sensitivity to the same antibiotic. *E. coli* isolated from layers were 32.26 % very susceptible to kanamycin and 64.52 % moderately sensitive to cephalexin, whereas 25 % and 19.39 % of layer isolates were less sensitive to chloramphenicol and kanamycin, respectively. However, 25% of isolates were seen as highly sensitive to chloramphenicol. In the study [48], they reported that 50 - 66.6 % of bacteria had high susceptibility to chloramphenicol and gentamicin. A study by [49] reported a sensitivity of *E. coli* to gentamicin at 36 % and to erythromycin at 100 %. In the study of [18], it was indicated that *E. coli* strains exhibited susceptibility to Norfloxacin, Gentamicin, Chloramphenicol, Neomycin, Tetracycline, Streptomycin, and Ampicillin, with respective susceptibility rates of 86 %, 80 %, 60 %, 36 %, 30 %, and 26 %.

Numerous studies indicate that isolates of *E. coli* from humans [50], domestic water [51] and poultry [20] exhibited complete susceptibility to carbapenem. Carbapenem antibiotics were designated as "last-line agents" due to their application in treating infections caused by multidrug-resistant bacteria that were unresponsive to other antibiotic classes [52]. The study of [25] reported that *E. coli* isolates had a susceptibility of

56.76 % to both ceftriaxone and gentamicin, with colistin following at 48.65 % susceptibility. This table indicates that the antibacterial susceptibility of many medications is diminishing progressively. Table 3 displays the resistance characteristics of various antimicrobial agents. *E. coli* isolated from broilers exhibited 100 % resistance to nalidixic acid, 97.14 % resistance to cloxacillin, 91.42 % resistance to erythromycin, and 62.85 % resistance to ampicillin [17]. All *E. coli* isolates from strata exhibited resistance to cloxacillin and nalidixic acid, with 93.55 % demonstrating resistance to erythromycin. Furthermore, 32.26 % of layer isolates resisted Ciprofloxacin, while 25.81 % demonstrated resistance to Ampicillin. The study of [48] reported that *E. coli* isolates from broiler and layer in Bangladesh exhibited resistance to chloramphenicol, ampicillin, ciprofloxacin, tetracycline, and streptomycin in 37 - 87.5 % of cases. Between 66 % and 100 % of *E. coli* bacteria obtained from poultry in Bangladesh exhibited resistance to tetracycline, penicillin, erythromycin, and chloramphenicol [49]. Another study by [18] discovered that no strain exhibited susceptibility to erythromycin, rifampicin, kanamycin, cefixime, penicillin, and ciprofloxacin, nor resistance to gentamycin and norfloxacin. Approximately 88 %, 82 %, 80 %, 76 %, 70 %, 68 %, 64 %, 58 %, 52 %, and 20 % of the tested *E. coli* strains from poultry sources exhibited resistance to penicillin, ciprofloxacin, rifampicin, kanamycin, streptomycin, cefixime, erythromycin, ampicillin, tetracycline, chloramphenicol, and neomycin, respectively. Bacteria exhibiting intermediate resistance to 11 different antibiotics (penicillin, ciprofloxacin, riphampicin, kanamycin, cefixine, erythromycin, ampicillin, tetracycline, and neomycin) varied from 12 % to 36 %. Over 55 % of the 101 pathogenic *E. coli* isolates examined in the study by [19] showed resistance to one or more drugs, with 36.6 % of the isolates displaying multidrug resistance traits. *E. coli* exhibited resistance to ampicillin (25.7 %), nalidixic acid (25.7 %), trimethoprim-sulphamethoxazole (26.7 %), tetracycline (45.5 %), and streptomycin (20.8 %). The isolates exhibited resistance to ciprofloxacin (12.9 %), chloramphenicol (8.9 %), nitrofurantoin (2 %), and gentamicin (2 %), but were susceptible to tigecycline and did not produce extended-spectrum beta-lactamase (ESBL). One isolate exhibited no development of ESBLs; nonetheless, it demonstrated resistance to mecillinam (1 %), cefuroxime (1 %), and cefadroxil (1 %) [19]. A study by [18] documented a 100 % resistance rate to ciprofloxacin, while [20] indicated an 82 % resistance rate in poultry. The study of [53] found that *E. coli* isolates from broiler cloacal swab samples in the Rajshahi district of Bangladesh exhibited nearly 100 % resistance to ampicillin, tetracycline, and trimethoprim-sulfamethoxazole. Consequently, unregulated antibiotic consumption without a prescription fosters the emergence and dissemination of antimicrobial resistance [54, 55]. *E. coli* isolated from cloacal swabs of broiler poultries exhibited 83 % resistance to levofloxacin, while *E. coli* acquired from a cloacal swab of poultry showed 31.66 % and 10 % resistance to meropenem and imipenem, respectively [56]. According to [25] *E. coli* isolates exhibited complete resistance to ampicillin and tetracycline. They exhibited a resistance of 91.89 % to nalidixic acid and 94.59 % to sulfamethoxazole-trimethoprim. A study by [8] determined that all 36 *E. coli* isolates possessing Avian Pathogenic *Escherichia Coli* (APEC)-associated virulence genes exhibited resistance to ampicillin and tetracycline (100 %), chloramphenicol and erythromycin (97.2 %), enrofloxacin (55.5 %), norfloxacin and ciprofloxacin (50 %), streptomycin (19.4 %), colistin (11.1 %), and gentamicin (8.3 %). *E. coli* strains isolated from broiler farms and their surroundings showed resistance to oxytetracycline, while 78.4 % demonstrated resistance to ciprofloxacin [27]. The study of [57] demonstrated that Avian Pathogenic *E. Coli* (APEC) isolates exhibited complete resistance to ampicillin and tetracycline. A significant issue involved the unregulated sale of antibiotics without prescriptions, which promoted irrational, excessive, and improper use in both animal and human health across most developing countries, including Bangladesh [58, 59, 47]. According to [29], 52 % of the collected *E. coli* showed resistance to four to seven distinct antimicrobials. Tetracycline exhibited the highest resistance level at 66 %, followed by erythromycin at 42 %, ampicillin and streptomycin at 38 %, and sulfonamide at 28 %. Ninety percent of *E. coli* showed resistance to multiple pharmaceuticals. Ciprofloxacin and enrofloxacin exhibited the highest resistance in poultry at 85 %, followed by ampicillin at 77 %, tetracycline at 74 %, and sulfamethoxazole-trimethoprim at 69 %. [30].

The study of [28] demonstrated that *E. coli* exhibited resistance rates of 81.6 % to levofloxacin, 78.1 % to cefotaxime, and 78.1% to doxycycline, with ciprofloxacin showing the highest resistance at 70. 2%. Ceftazidime had the lowest resistance rate at 1.8 %, succeeded by ceftriaxone at 7.9 % and colistin at 14.9 %. Significantly, imipenem (65.8 %) and meropenem (50.9 %), classified as carbapenems, demonstrated considerable resistance due to their absence in Bangladeshi poultry operations. Approximately 76 % of *E. coli* isolates exhibited multidrug resistance; specifically, the rates were 78.8 %, 76.3 %, and 74.4 % for hand-washed water, farm sewage, and cloacal swabs, respectively. Seventy percent of isolates showed resistance to 4 – 7 antibiotics, while only 27 % and 3.5 % indicated resistance to 1 – 3 and 8 – 9 medicines, respectively. According to [31], it was discovered that *E. coli* isolates subjected to ampicillin exhibited significant resistance, with prevalence rates between 73.7 % and 100 % for ampicillin, 100 % for penicillin, 83.3 % to

100 % for amoxicillin, 20.2 % to 41.9 % for the combination of amoxicillin and clavulanate acid, and 28.6 % to 70.9 % for the combination of piperacillin and tazobactam. *E. coli* isolates exhibited a spectrum of resistance to cephalosporin antibiotics: 2.3 – 100 % for ceftriaxone, 53.5 – 100 % for cefotaxime, 1.8 – 57.1 % for ceftazidime, 46.5 – 100 % for cephalexin, and 72.1 – 85.7 % for cefepime. Furthermore, isolates of *E. coli* exhibited resistance to cefuroxime, cefixime, cephradine, and cefaclor. Moreover, *E. coli* isolates exhibited differing levels of resistance to carbapenems (imipenem: 13.6 – 65.8 %; meropenem: 41.9 – 72.7 %) and additional classes of antibiotics. Escherichia coli isolates from poultry and poultry environments in Bangladesh exhibited resistance to fluoroquinolones, including levofloxacin (22.2 – 83 %), ciprofloxacin (6 – 100 %), nalidixic acid (61.6 – 100 %), norfloxacin (5.98 – 50 %), gatifloxacin (38.9 – 50 %), pefloxacin (61.1 - 88.4 %), and ofloxacin (55.6 - 56.9 %). Aminoglycoside antibiotics, including gentamicin (6 - 100 %), streptomycin (16.4 – 100 %), and neomycin (27.9 – 100 %), showed resistance to the isolated strain of *E. coli*. *E. coli* isolated from poultry exhibited various combinations of resistance, including tetracyclines (tetracycline: 17.7 – 100 %; oxytetracycline: 93 – 100 %; doxycycline: 68.6 - 78.9 %), macrolides (erythromycin: 16.2 -100 %; azithromycin: 11.8 - 34.9 %), and polymyxins (colistin: 10.5 – 100 %; polymyxin B: 7.9 - 8.1 %). Moreover, they demonstrated resistance to various antibiotics, including phenicol (20 – 97.2 %), sulfa drugs/folate pathway inhibitors (44.7 – 100 %; sulfamethoxazole-trimethoprim, prevalence: 44.7 –100 %), cephamycins (21.4 –48.8 %), nitrofurans (21.4 – 63.2 %), monobactams (1.2 %), and glycylcyclines (2.3 %). The study of [31] also reported that multidrug resistance profiles of *E. coli* in poultry were identified in 14 of 17 publications, indicating a resistance rate of 82.4 %. Escherichia coli demonstrated multidrug resistance between 10 % and 100 %. Furthermore, it was found that 64.3 % of the samples had *E. coli* that exhibited complete resistance to antibiotics. Moreover, the study of [32] indicated that antimicrobial resistance profiling of *E. coli* isolates from broilers demonstrated the highest resistance frequency to sulphamethoxazole-trimethoprim (89 %), followed by tetracycline (87 %), ampicillin (83 %), and ciprofloxacin (61 %). *E. coli* isolates exhibited resistance to cephalexin (37 %), gentamicin (32 %), and colistin sulfate (21 %). Furthermore, they indicated that most *E. coli* isolates from broiler meat had resistance to three or more antimicrobial drugs. This analysis indicated a rapid decline in the sensitivity of several antimicrobial medicines. Nonetheless, the increasing resistance of *E. coli* to the majority of antimicrobial agents is alarming, not just for the poultry sector but also for farmers, stakeholders, and public health.

Resistance gene of E. coli

The mutation of genotype and development of resistance genes to resist different antimicrobials are shown in Table 3. In Bangladesh, Extended-Spectrum Beta-Lactamase (ESBL)-producing *E. coli blaCTX-M-1* (94.4 %) and *blaTEM* (50 – 91.3 %) were identified in poultry excrement by [60, 24].

According to [25] every *E. coli* isolate had the *blaTEM*, *tetA*, and *Sul2* genes and was multidrug-resistant (MDR). Moreover, they reported that of the 37 isolates resistant to tetracycline and ampicillin, 28 of them tested positive for the *blaTEM* gene, which encodes ampicillin resistance genes, while 15 isolates tested positive for the *tetA* gene, which encodes tetracycline resistance genes. Thirteen isolates out of the 35 isolates resistant to trimethoprim-sulfamethoxazole showed the *Sul2* gene, which codes for sulfur drug resistance. In the study of [29], they identified *aac3-IV* genes (44 %), *blaCITM* (48 %), *blaSHV* (40 %), *tetA* (66 %), *ereA* (64 %), *tetB* (60 %), *aadA1* and *sulI* (56 %), and *blaSHV* (40 %) as the predominant antimicrobial resistance genes (ARGs). Another study by [32] report that a substantial proportion of *E. coli* exhibited multi-drug resistance (MDR). *TetA* was present in 84 % of the tetracycline-resistant isolates. 3.6 % of isolates were identified as *tetD* in this study conducted in Bangladesh, while 0.5 % of the remaining isolates were *tetC*, and 6.0 % possessed two genes, among others. Escherichia coli isolated from sheep, cattle, poultry, and humans had several resistance genes for ampicillin (*blaTEM*), tetracycline (*tetA*, *tetB*, *tetC*), and sulfamethoxazole-trimethoprim (*sul1*, *sul2*). These genes were identified by [30]. Approximately 58.8% of the articles analyzed by [31] reported the presence of antibiotic resistance genes associated with beta-lactams (*blaTEM*, *blaCTXM-1*, *blaCTX-M-2*, *blaCTX-M-9*, *blaOXA-1*, *blaOX*, and *CITM*), tetracyclines (*tetA*, *tetB*, and *tetC*), sulfonamides (*sulI* and *sulII*), fluoroquinolones (*qnrB* and *qnrS*), colistin (*mcr1* and *mcr3*), aminoglycosides (*rmtB*), streptomycin (*aadA1*), gentamicin (*aac-3-IV*), erythromycin (*ereA*), trimethoprim (*dfrA1*), and chloramphenicol (*catA1* and *cmlA*) (Table 4). The prevalence of these resistance genes ranged from 1.2 - 100 % among instances. The international community is apprehensive regarding the increase in resistant genes.

Causes of Antimicrobial Resistance (AMR) in the Poultry Industry in Bangladesh

In Bangladesh, poultry and livestock agriculture systems have transitioned from small-scale domestic farms to medium- and large-scale commercial enterprises [61, 62]. Farm owners frequently depended on unlicensed and informal healthcare providers for animal treatment due to the absence of an adequate governmental framework for animal healthcare. Consequently, the overuse, abuse, and inadequate or excessive application of antibiotics in agriculture stem from their irrational prescribing and easy accessibility [61]. Moreover, antibiotics were intermittently employed to promote growth and serve as a prophylactic measure, especially in the extensive commercial farms of Bangladesh [63]. Various species of pathogenic and zoonotic antibiotic-resistant bacteria have evolved in animal farming environments in Bangladesh due to irrational, suboptimal, or excessive antibiotic usage [56, 67, 65, 66]. The rising prevalence of Antimicrobial Resistance (AMR) in Bangladesh may be substantially affected by the accessibility and availability of over-the-counter antibiotics at feed dealer shops and pharmacies [67]. Despite their inadequate understanding of the effects of excessive and preventive antibiotic usage on the development of Antimicrobial Resistance (AMR), a significant number of suppliers of animal feed and pharmaceuticals advised farmers to utilize antimicrobials in poultry production [58]. The absence of state-specific veterinary healthcare, regulatory oversight, and monitoring services, coupled with the farmers' constrained financial resources, has facilitated the influence of unlicensed village doctors, poultry and feed merchants, and pharmaceutical sales representatives on the decisions of animal farm proprietors. Farmers were driven to misuse or excessively utilize antibiotics due to the increasing need for animal-derived protein and the insufficient knowledge regarding treatments, diseases, and the incidence of antimicrobial resistance. Antimicrobial Resistance (AMR) infections have arisen in animals in Bangladesh due to a deficient regulatory framework for antimicrobial monitoring programs and several irregularities in antibiotic usage in veterinary practices [68].

Correlation of Antimicrobial Resistance (AMR) with Poultry, Human Health, and Environment

There is a significant link between antibiotic resistance among poultry, the environment, and human health. A study by [31] indicated that inadequate hygienic practices on farms and insufficient understanding among poultry farmers regarding optimal poultry farming systems significantly contributed to the elevated frequency of *E. coli* in poultry and their habitats. The increased exposure to *E. coli* in poultry and their environment is a risk to both poultry farming and human health. Humans contracted the infections from undercooked meat and eggs, as well as from exposure to infected birds at farms or slaughterhouses. Emerging issues in poultry health management and biosecurity present a substantial risk for zoonotic disease transmission to humans. In Bangladesh, antimicrobials were extensively utilized in food animals, especially in poultry for prophylactic and therapeutic applications [69]. The indiscriminate use of antibiotics in food animals is a primary contributor to the evolution of Antimicrobial Resistance (AMR) in both pathogenic and commensal bacteria. The poultry production system was deemed a significant danger for the emergence of Antimicrobial Resistance (AMR) in low-income regions, especially in Bangladesh, where commercial poultry production was seeing rapid growth. The findings of [10] indicate that most kinds of antimicrobials were utilized in both humans and avian species. The detection of residues from various antibiotics (ciprofloxacin, enrofloxacin, amoxicillin, doxycycline, oxytetracycline, and tetracycline) in poultry meat [70] and eggs [71] has been implicated in the development of antimicrobial resistance in humans. The findings of [27] indicated that numerous poultry farmers regarded the administration of one or more antibiotics at various stages of avian development as a standard practice in poultry husbandry. The inappropriate use of antibiotics may contribute to the emergence of antimicrobial resistance (AMR) in commensal bacteria, such as *E. coli,* in poultry. Among the multidrug-resistant pathogens, *E. coli*, *Salmonella, Enterobacter, Staphylococcus, and Campylobacter spp.* represent potential zoonotic agents posing direct risks to human health [72]. In the study of [19], it was indicated that poultry litter is commonly utilized as fertilizer in agricultural production and aquaculture, potentially spreading resistant bacteria into the environment in Bangladesh. Antimicrobial Resistance 9AMR) *E. coli* obtained from humans shown similarities to *E. coli* sourced from poultry [73]. A study by [74] found an increase in the prevalence of ESBL-producing *E. coli* in humans and animals in various regions globally. A study by [75] indicating that *E. coli* isolated from poultry flesh shown resistance to 13 distinct types of antibiotics, raising concerns among the healthcare community. An international epidemic of antibiotic resistance poses a significant threat to human health, as highlighted by [76]. Extended-Spectrum Beta-Lactamase (ESBL)-producing *E. coli* has been associated with the diminished efficacy of various antimicrobial classes, including tetracyclines, aminoglycosides, fluoroquinolones, and trimethoprim-sulfamethoxazole, which exacerbate healthcare outcomes, prolong hospitalizations, increase treatment expenses, and complicate maintenance [77, 78]. The presence of *E. coli* in poultry and their habitats has raised significant concerns due to its contribution to a global crisis in the supply of antibiotic treatment alternatives. A study conducted by [79] indicates that commensal *E. coli* may act as a significant reservoir of resistance genes, capable of transferring these genes to pathogens within hosts and the human intestinal tract following the ingestion of contaminated animal-derived foods.

Prevention and control of E. coli infection

Two key factors in preventing colibacillosis are minimizing exposure to Avian Pathogenic *E. coli* (APEC) and addressing stress and related diseases that heighten birds' vulnerability to infection. Additionally, a variety of commercial and experimental vaccines are available to prevent colibacillosis, though their effectiveness varies. Implementing biosecurity protocols and vaccination programs within poultry flocks is essential to lower the risk of serious diseases. Furthermore, reducing ammonia and dust levels in barns can help decrease the environmental stressors that often enable *E. coli* to infect a flock.

Way of Mitigation of Antimicrobial Resistance (AMR) in Poultry

Antimicrobial Resistance (AMR) presents substantial threats to human, animal, and environmental health, necessitating collaborative initiatives among several sectors and stakeholders for its elimination. In Bangladesh, numerous poultry production facilities frequently neglect biosecurity, safety, and hygiene rules, posing a significant hazard. Upholding hygiene, adhering to appropriate manufacturing protocols, and implementing stringent biosecurity measures are essential for mitigating the transmission of zoonoses and averting colibacillosis in poultry farms. An urgent necessity exists to enhance awareness and undertake scientifically rigorous investigations via monitoring and surveillance initiatives to mitigate the detrimental effects of antimicrobial-resistant *E. coli* in the poultry sector. A comprehensive national monitoring system is crucial to mitigate the illicit use of antibiotics in poultry farming.

National action plan on the Antimicrobial Resistance (AMR) issue in Bangladesh

In 2015, the World Health Organization (WHO) approved the Global Action Plan (GAP) to address the escalating global menace of Antimicrobial Resistance (AMR), utilizing the "One Health" framework, as emphasized by [80]. The Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE) offered complementary solutions with analogous objectives, as indicated by [63]. Following the World Health Organization (WHO) Good Agricultural Practices (GAP), Bangladesh prepared and ratified a National Action Plan (NAP) for 2017-2022 to combat Antimicrobial Resistance (AMR) across human, animal, and environmental domains. Coordinated actions across all sectors are important for the successful execution of this NAP. Bangladesh is presently executing its National Action Plan for Antimicrobial Resistance containment within the "One Health" framework, with the Department of Livestock Services (DLS) tasked with implementing NAP tactics within the animal health sector. The findings of [80] underscore the importance of comprehending the present status of AMR across human, animal, and environmental domains for advancement. Although numerous research [66, 81, 82, 83, 84] have elucidated the patterns and prevalence of antimicrobial resistance in zoonotic diseases in Bangladesh, further investigation by the Department of Livestock Services is warranted. Before launching a comprehensive Antimicrobial Resistance (AMR) surveillance initiative in the animal health sector, it is crucial to identify existing knowledge deficiencies through a meticulous analysis of the problem's origin and breadth. National Strategic Plan (NSP) and National Action Plan (NAP) on Antimicrobial Resistance (AMR), 2021 to 2026, featuring a "National AMR Containment Program." National surveillance for antimicrobial resistance in human health, animal health, and antimicrobial consumption was continuing. The utilization of antimicrobials in agriculture has contributed to the global rise of Antimicrobial Resistance (AMR). The issue of Antimicrobial Resistance (AMR) has been recognized as particularly appropriate for the implementation of the One Health concept. Recently, the concept "One Health" has emerged to integrate viewpoints from the animal, environmental, and human health sectors to mitigate illness risks in people and other animals [85]. The framework has been adopted in Bangladesh, where, similar to numerous other low- and middle-income countries (LMICs), a significant fraction of the population depends on livestock for sustenance or revenue, as indicated by [80] and [86]. It has been asserted that the Ganges floodplain, where Bangladesh is located, 'supports more persons and animals than any other region on earth' [87]. The high population of humans and animals facilitated the dissemination of diseases and resistance genes. The widespread availability of antimicrobials, coupled with their growth-promoting effects, provides numerous incentives for individuals to administer these drugs to their animals, resulting in significant indiscriminate usage in both terrestrial and aquatic species [88, 80]. The Bangladesh government sanctioned the "Bangladesh Fish Feed and Animal Feed Act, 2010" in 2010, which prohibited the incorporation of antibiotics, growth hormones, steroids, and pesticides into animal feed during production (Gazette Bangladesh, 2020). The study of [89] indicated in his report that the overuse of antimicrobials in animals may result in the emergence of resistant bacteria and infections within the animals, thereby diminishing their productivity and jeopardizing human food security and economies. Furthermore, it could facilitate the spread of antimicrobial residues and resistant bacteria into the environment and communities. Over a decade ago, the Ministry of Fisheries and Livestock acknowledged that the restricted capacity of veterinary services and regulatory enforcement had impeded efforts to tackle Antimicrobial Resistance (AMR) in the 2007 National Livestock Development Policy [80]. The national government implemented three regulations from 2010 to 2013 that restrict the use of antimicrobials in animal and fish feed for growth promotion, violations of which may result in a year of jail or a fine of US$650 [80, 86]. The observation of [89] noted that the Bangladesh Antimicrobial Resistance Alliance (BARA) was founded with the help of the WHO and FAO, and funded by the Bangladeshi government. Utilizing a One Health strategy, it convened veterinary and medical specialists to formulate recommendations for addressing Antimicrobial Resistance (AMR) within each sector. The guidelines were subsequently accessible through a mobile application for field use and a training program, while a social media-based 'community of practice' was established to encourage practitioners, including veterinarians, animal health workers, and extension officers, to exchange advice and resources [90, 91]. The One Health Secretariat established in Bangladesh, coupled with training programs for farmers on the judicious use of antimicrobials initiated by the Department of Livestock Services (DLS), has positioned BARA as a commendable example of AMR policy implementation in Bangladesh [86]. The Bangladeshi National Action Plan for Antimicrobial Resistance (BNAP) was established as the national policy to combat Antimicrobial Resistance (AMR), following the WHO's directive for nations to adopt plans to tackle this issue [92]. A roadmap was initiated in 2017 to execute the plan [93]. By 2050, it is projected that, in the absence of intervention, Antimicrobial Resistance (AMR) will result in 300 million human fatalities, financial losses amounting to US$100 trillion, and an 11% decline in animal productivity [94]. Low and middle-income countries (LMICs) in Africa and Asia will see the most significant effects [94]. Bangladesh is at a significant risk of Antimicrobial Resistance (AMR), despite its location in the Southeast Asia region, as noted by [95]. The participation of regulatory bodies, especially the Department of Livestock Services (DLS), in conjunction with licensed veterinary professionals, is essential for the execution of antibiotic stewardship programs to mitigate the escalating risk of Antimicrobial Resistance (AMR). This study aims to solve information gaps about antimicrobial resistance (AMR) by examining prior studies on the Antimicrobial Resistance (AMR) status in Bangladesh's animal health sector. The government of Bangladesh implemented the "Fish Feed and Animal Feed Act, 2010" and the "Animal Feed Rule, 2013," prohibiting antibiotics in animal feed and regulating colistin, a vital antibiotic. These regulations authorized the DLS to designate staff for essential enforcement functions, including investigations, arrests, searches, seizures, and prosecutions, to avert the misuse of antibiotics in animal feed. Bangladesh is implementing its National Action Plan (NAP) for Antimicrobial Resistance (AMR) containment across human, animal, and environmental sectors utilizing the "One Health" strategy. A collaborative endeavor among all implementing partners, coupled with robust commitment and engagement, is crucial for effectively addressing AMR and maintaining the One Health philosophy. The NAP appointed the DLS to execute initiatives designed to fulfill strategic goals for reducing AMR in veterinary clinics. Despite the DLS executing these responsibilities, notable policy deficiencies persist, including the absence of a definitive finance structure, explicit standards for antimicrobial stewardship in the veterinary domain, and thorough operational, monitoring, and evaluation systems [86].

Conclusion and Recommendation

Antimicrobial Resistance (AMR) is regarded as one of the most significant worldwide health threats, with Bangladesh recognized as being at elevated risk. The establishment and zoonotic transmission of antibiotic-resistant bacteria or associated resistance genes is significant due to their prevalence in agricultural settings, including soil, water, and animal products and by-products. Antimicrobial Resistance (AMR) is a "One Health" concern, necessitating the integration of the veterinary industry for its effective management. Consequently, this research aims to elucidate the existing status and identify the knowledge gaps regarding the burden of antimicrobial resistance in Bangladesh's veterinary sector. This comprehensive analysis of the Antimicrobial Resistance (AMR) status in Bangladesh's poultry practices aims to acquire and analyze the maximum accessible data. Nonetheless, constraints emerged from restricted access to specific databases and the stringent data-sharing policies of particular periodicals. This review is comprehensive yet offers significant insights into the underlying causes of Antimicrobial Resistance (AMR) and the present state of Antimicrobial Resistance (AMR) in veterinary practices in Bangladesh. This review paper may serve as a reference for the development and implementation of future Antimicrobial Resistance (AMR) containment efforts in the veterinary industry of Bangladesh. This assessment seeks to inform policymakers and furnish vital assistance to researchers and Department of Livestock Services (DLS) authorities in addressing this pressing issue decisively.

Acknowledgments

Not applicable.

Funding statement

This study didn't receive any funding support

Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

TABLE. 1 Prevalence of *E. coli* in Poultry species

Species of Bird	Prevalence of *E. coli*	References
Broiler	63.6 %; 36.20 %; 82 %; 100 %; 61.67 %; 44.67%; 76 %; 31.25 %; 56.5 %; 24.3 – 100 %; 100 %; 59.3 %;	**[17], [19], [20], [21], [25], [26], [28], [29], [32], [31]; [24], [27]**
Layer	56.4 %; 80 %; 85 %; 82.83 %; 61.3 - 82.8 %;	**[17], [22], [23], [8]**
Overall Poultry	62.5 %; 60.0 %; 58 %; 78 %; 69.3 %	**[16], [17], [18], [30], [31]**

TABLE 2. Antimicrobial sensitivity profile of *E. coli* against different antibiotics

Poultry	Sensitive to Antimicrobial drugs	References
Layer	Kanamycin & Cephalexin (32.26 %); chloramphenicol (25 %)	**[17]**
Broiler	Chloramphenicol (54.28 %); Kanamycin (14.29 %); Ciprofloxacin (22.86 %) Chloramphenicol (54.28 %); Kanamycin (14.29 %); Ciprofloxacin (22.86 %) Chloramphenicol (54.28 %); Kanamycin (14.29 %); Ciprofloxacin (22.86 %) Chloramphenicol (54.28 %); Kanamycin (14.29 %); Ciprofloxacin (22.86 %) Ceftriaxone and Gentamicin (56.76 %); Colistin (48.65 %)	**[25]**
Broiler and Poultry	Chloramphenicol & Gentamicin (50 - 66.6 %)	**[48]**
Poultry	Gentamicin (36 %); Erythromycin (100 %)	**[49]**
	Norfloxacin (86 %), Gentamicin and Chloramphenicol (80 %), Neomycin (60 %), Tetracycline (36 %), Streptomycin (30 %), and Ampicillin (26 %)	**[18]**
	Carbapenem (100 %)	**[20]**

TABLE 3. Antimicrobial Resistance profile of *E. coli* against different antibiotics

Poultry	Resistance	References
Layer	Cloxacillin (100 %); Nalidixic Acid (100 %); Erythromycin (93.55 %); Ciprofloxacin (32.26 %); Ampicillin (25.81 %)	**[17]**
	Ampicillin & Tetracycline (100 %); Chloramphenicol & Erythromycin (97.2 %); Enrofloxacin (55.5 %); Norfloxacin & Ciprofloxacin (50.0 %); Streptomycin (19.4 %); Colistin (11.1 %); and Gentamicin (8.3 %)	[8]
Broiler	Nalidixic Acid (100 %); Cloxacillin (97.14 %); Ampicillin (62.85 %) Erythromycin (91.42 %)	**[17]**
	Ampicillin, Tetracycline, & Trimethoprim-Sulfamethoxazole (100 %)	**[53]**
	Levofloxacin (83 %); Meropenem (31.66 %) & Imipenem (10 %)	**[24]**
	Ampicillin & Tetracycline (100 %); Sulfamethoxazole-Trimethoprim (94.59 %); Nalidixic acid (91.89 %)	**[25]**
	Oxytetracycline (100 %) & Ciprofloxacin 78.4 %)	**[27]**
	Levofloxacin (81.6 %), Cefotaxime (78.1 %), Doxycycline (78.1 %), Ciprofloxacin (70.2 %); Imipenem (65.8 %); Meropenem (50.9 %); Ceftazidime (1.8 %) Ceftriaxone (7.9 %) and Colistin (14.9 %)	**[28]**
	Sulphamethoxazole–trimethoprim (89 %), tetracycline (87 %), ampicillin (83 %), ciprofloxacin (61 %), cephalexin (37 %), gentamicin (32 %), and colistin sulfate (21 %)	**[32]**
Poultry	Tetracycline, Penicillin, Erythromycin & Chloramphenicol (66 - 100 %)	**[49]**
	Ciprofloxacin (100 %)	**[20]**
	Erythromycin (42 %); Ampicillin & Streptomycin (38 %) and Sulfonamide (28 %)	**[29]**
	Penicillin (100 %); Amoxicillin (83.3 – 100 %); Combination of Amoxicillin and Clavulanate Acid (20.2 - 41.9 %); Combination of Piperacillin and Tazobactam (28.6 - 70.9 %); Ceftriaxone (2.3 – 100 %); Cefotaxime (53.5 – 100 %); Ceftazidime (1.8 - 57.1 %), Cephalexin (46.5 – 100 %); Cefepime (72.1 - 85.7 %); Ciprofloxacin (6 – 100 %), Levofloxacin (22.2 – 83 %), Nalidixic Acid (61.6 – 100 %), Norfloxacin (5.98 – 50 %), Gatifloxacin (38.9 – 50 %), Pefloxacin (61.1 -88.4 %), Ofloxacin (55.6 - 56.9 %); Imipenem (13.6 - 65.8 %) & Meropenem (41.9 - 72.7); gentamicin (6 – 100 %), streptomycin (16.4 – 100 %), and neomycin (27.9 – 100 %); tetracycline (17.7 – 100 %), oxytetracycline (93 – 100 %), doxycycline (68.6 - 78.9 %); erythromycin: (16.2 – 100 %) & azithromycin (11.8 - 34.9 %); colistin (10.5 – 100 %) and polymyxin B (7.9 - 8.1 %); chloramphenicol (20 - 97.2 %); sulfamethoxazole-trimethoprim (44.7 – 100 %), sulfonamides (44.7 %), cefoxitin (21.4 - 48.8 %); nitrofurantoin (21.4 - 63.2 %); aztreonam (1.2 %); tigecycline (2.3 %).	**[31]**
Broiler & other Poultry	Chloramphenicol, Ampicillin, Ciprofloxacin, Tetracycline & Streptomycin (37 - 87.5 %)	**[48]**
Poultry & Poultry Environment	Penicillin (88 %), Ciprofloxacin (82 %), Riphampicin (80 %), Kanamycin (76 %), Streptomycin (70 %), Cefixime (68 %), Erythromycin (64 %), Ampicillin (58 %), Tetracycline (52 %), Chloramphenicol (20 %) & Neomycin (20 %)	**[18]**
Poultry farm	Tetracycline (45.5 %); Trimethoprim-Sulphamethoxazole (26.7 %); Nalidixic Acid (25.7 %); Ampicillin (25.7 %) & Streptomycin (20.8 %)	**[19]**
Frozen poultry	Ciprofloxacin & Enrofloxacin (85 %); Ampicillin (77 %); Tetracycline (74 %); and Sulfamethoxazole-Trimethoprim (69 %)	**[30]**

TABLE 4. Resistance gene of *E. coli* found in poultry in Bangladesh.

Resistance gene of *E. coli*	References
blaCTX-M-1, blaTEM	**[60]**, **[24]**
blaTEM, tetA, and Sul2	**[25]**
tetA, ereA, tetB, aadA1 and sulI, blaCITM, blaSHV, and aac3-IV genes .	**[29]**
tetA, tetB, tetC, tetD	**[32]**
tetA, tetB, tetC, (blaTEM), sul1, sul2	**[30]**
blaTEM, blaCTXM-1, blaCTX-M-2, blaCTX-M-9, blaOXA-1, blaOX, and CITM, tetA, tetB, and tetC, sulI and sulII, qnrB and qnrS, mcr1 and mcr3, rmtB, aadA1, aac-3-IV, ereA, dfrA1, and catA1 and cmlA	**[31]**

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