

**Review on Antimicrobial Resistance Pattern of Similar Antibiotics Used for *Escherichia Coli* and *Salmonella* Spp. in Bangladesh with Public Health Significance**

## ABSTRACT

Antimicrobial resistance (AMR) is a major health threat for humans and animals around the world. Different classes of antibiotics are frequently used to treat human, poultry, and livestock diseases in Bangladesh. *Escherichia coli* and *Salmonella* spp. cause gastrointestinal illness in humans and animals. Since they have zoonotic potential, their antibiotic resistance genes may transfer both horizontally and vertically. Human, poultry, and livestock excreta and their environment are excellent sources of pathogenic bacteria. Therefore, *E. coli* and *Salmonella* infections in humans and animals are frequently found here, causing huge economic losses. To treat this type of infection, similar generic antibiotics are used indiscriminately in humans, poultry, and livestock. In this study, different types of antibiotics like ampicillin, ceftriaxone, ciprofloxacin, gentamicin, erythromycin, azithromycin, tetracycline, sulphamethoxazole-trimethoprim, and colistin were found to have higher levels of resistance against *E. coli* and *Salmonella* spp. Due to a higher level of resistance, two or three types of antibiotic combinations are used today to check bacterial infections that increase the medicinal burden. It is high time to combat AMR infections by raising public awareness, and the government should implement a national action policy to combat illegal antibiotic use.

**Keywords:** AMR; *E. coli*; *Salmonella*; zoonotic; humans; poultry; livestock.

## 1. INTRODUCTION

The issue of antimicrobial resistance (AMR) affects public health worldwide [1, 2]. AMR increases the number of deaths and hospitalizations while also increasing medical costs [1]. It also affects the poultry and livestock sectors simultaneously [3,4]. Each year, AMR is responsible for hundreds of thousands of fatalities [5]. AMR is predicted to cause around 10 million yearly deaths worldwide by the year 2050 [6]. According to the WHO, AMR is among the top 10 worldwide public health hazards to humanity [7,8]. According to World Bank estimations, with modest AMR impacts, the world's annual gross domestic product (GDP) will probably decline by 1.1% by 2050, while in a high AMR adverse situation, the global GDP would fall by 3.8% by 2050, with an annual shortfall of 3.4 trillion US dollar by 2030 [9]. AMR would also result in greater economic growth declines in least developed countries than in developed countries, increasing economic disparity across nations [10]. The highest AMR effect scenario projects a probable 11% reduction in livestock productivity in low-income nations by 2050 [9].

*E. coli* is often found in the gastrointestinal tracts of humans and animals. *E. coli* strains are not commonly detrimental. But some strains such as Shiga toxin-producing *E. coli* (STEC), can cause severe foodborne diseases. Around the world, 20% of cases of foodborne diseases are caused by *E. coli* O157:H7 [11]. Salmonellosis is an ordinary bacterial disease condition which is responsible for gastrointestinal illness. *Salmonella* spp. generally lives in the intestines of humans and animals and is shed in feces. CDC reported that *Salmonella* generates 1.35 million illnesses, 26,500 hospital admissions, and 420 human deaths annually in the US [12]. Both *E. coli* and *Salmonella* spp. have zoonotic significance and cause severe production losses in dairy and poultry [3,4].

Different classes of antibiotics have been widely used for the treatment of *E. coli* and *Salmonella* infections for decades. Antibiotics are becoming less effective due to their vast indiscriminate use. That's why several studies have been carried out on AMR for various bacterial species in humans, poultry, and livestock from time to time in Bangladesh. This study is designed to look into the use of similar kinds of antibiotics and their resistant patterns in humans, poultry, and livestock.

## 2. MATERIAL AND METHODS

We utilized the databases Google, Google Scholar, Pubmed, and ResearchGate for a search of pertinent literature on similar antibiotics used in humans, poultry, and livestock in Bangladesh. The keywords used to search databases were "AMR of *E. coli* and *Salmonella* in humans, poultry, and livestock from 2010 to 2022 in Bangladesh" and "AMR of *E. coli* and *Salmonella* in different divisions of Bangladesh;" "AMR of *E.*

*coli* and *Salmonella* in Bangladesh for livestock production;" "Antibiotic-resistant" or "antimicrobial-resistant" in poultry farming in Bangladesh. We also searched for AMR situations in hospital patients, chickens, and ruminants in Bangladesh. AMR of *E. coli* and *Salmonella* spp. in humans, poultry, and livestock around the world is also observed for the global burden and situation of AMR. We used Microsoft Word and Excel (MS-2013) for data curation and analysis.

### 3. SOURCE AND TRANSMISSION

#### 3.1 *E. coli*

The main reservoir for *E. coli* transmission is cattle [4]. Similarly, other livestock like sheep and goats are considered to be significant hosts, and some vertebrates including poultry, pigs, and horses, have also been detected as transport hosts [2, 11]. Humans are infected with *E. coli* O157: H7 and are often brought on by consuming contaminated foods such as uncooked meat or unpasteurized milk [11]. Cross-contamination with beef and other animal foods during cooking, diseased surfaces, and dirty kitchen tools are some ways that infection can happen. Another risk factor is fecal contamination of food, drink, and other sources [4].

#### 3.2 *Salmonella* spp.

*Salmonella* can be transmitted by food animals like chickens, pigs, and cattle [2, 4, 13]. It is also found in birds, reptiles, and turtles, as well as in pets like cats and dogs [13]. *Salmonella* may go up the food web from feedstuffs through primary production to homes, catering, and other locations where food is served [2]. Salmonellosis is most commonly transmitted in humans by consuming untreated water and contaminated foods of livestock origin [13]. It is also feasible for humans to transmit salmonellosis indirectly. [14]. Pet owners who come into contact with diseased animals may also get sick [13].

### 4. SIMILAR ANTIBIOTICS USED IN HUMAN, POULTRY AND LIVESTOCK

Antibiotics are drugs used to treat bacterial infections in both humans and animals [15]. Globally, different classes of antibiotics are used for the treatment of *E. coli* and *Salmonella* infections in humans, poultry, and livestock [16,17]. Several studies have been reported that penicillins, cephalosporins, quinolones, aminoglycosides, macrolides, tetracyclines, sulfonamides, and other classes of similar antibiotics are frequently used to treat *E. coli* infections in humans, poultry, and livestock in Bangladesh [Table 1].

**Table 1. List of similar antibiotics used in humans, poultry, and livestock in Bangladesh**

Class of antibiotics	Name of Antibiotics	References
Penicillins	i) Ampicillin	[18-26]
	ii) Amoxicillin	
Cephalosporins	i) Cephalexin	[17, 18, 23, 27-29]
	ii) Ceftriaxone	
Quinolones	i) Ciprofloxacin	[16, 18, 20, 24, 26, 28, 30-35]
	ii) Levofloxacin	
	iii) Norfloxacin	
	iv) Nalidixic Acid	
Aminoglycosides	i) Gentamicin	[18, 23, 36]
Macrolides	i) Erythromycin	[4, 22, 23, 28, 33, 37, 38]
	ii) Azithromycin	

Tetracyclines	i) Tetracycline	[4, 16, 18, 19, 32, 38-40]
	ii) Doxycycline	
Phenicols	i) Chloramphenicol	[4, 24, 33]
Sulphonamides	i) Sulphamethoxazole	[17, 20, 36, 41]
Polymyxins	i) Colistin	[3, 27, 42]

## 5. RESISTANT PATTERN OF *E. COLI* AND *SALMONELLA* SPP.

Antimicrobial resistance of *E. coli* and *Salmonella* spp. have become an alarming issue that is being encountered more frequently worldwide in both veterinary and human medicine. *Salmonella* and *E. coli* species have a strong potential to acquire resistance genes, despite the fact that all therapeutically significant antimicrobial medicines are fundamentally sensitive to them. In the case of *E. coli*, mostly through horizontal gene transfer [43], but for Salmonellosis, both horizontal and vertical transmission occur [2]. Table 2 represents the resistance pattern of similar antibiotics used for *E. coli* and *Salmonella* spp. infection in humans, poultry, and livestock in Bangladesh.

### 5.1 Resistance to Penicillins

Antibiotics from various classes are frequently used to treat *E. coli* and *Salmonella* infection. Ampicillin and amoxicillin are members of the  $\beta$ -lactam class of antibiotics which generally kill numerous bacterial pathogens [2]. In Bangladesh, ampicillin showed 87% to 100% resistance to *E. coli* and 100% to *Salmonella* from hospital patient samples, poultry, and cattle samples, respectively. Manhique-Coutinho et al. [70] reported 97.8% ampicillin resistant to *E. coli* from diarrheic children in Mozambique and 91% ampicillin resistance to *Salmonella* Typhimurium in China [71]. Racewicz et al. [72] detected 100% ampicillin resistance to *E. coli* from poultry in Poland, whereas 95.4% resistance was found from livestock in the UAE [73]. On the other hand, Elmadiena et al. [74] reported 90.60% ampicillin resistant to *Salmonella* from humans and animals in Sudan. Figure 1 shows resistance of ampicillin to *E. coli* and *Salmonella*, where 100% resistance was observed in the case of *Salmonella* among humans, poultry, and livestock in Bangladesh.

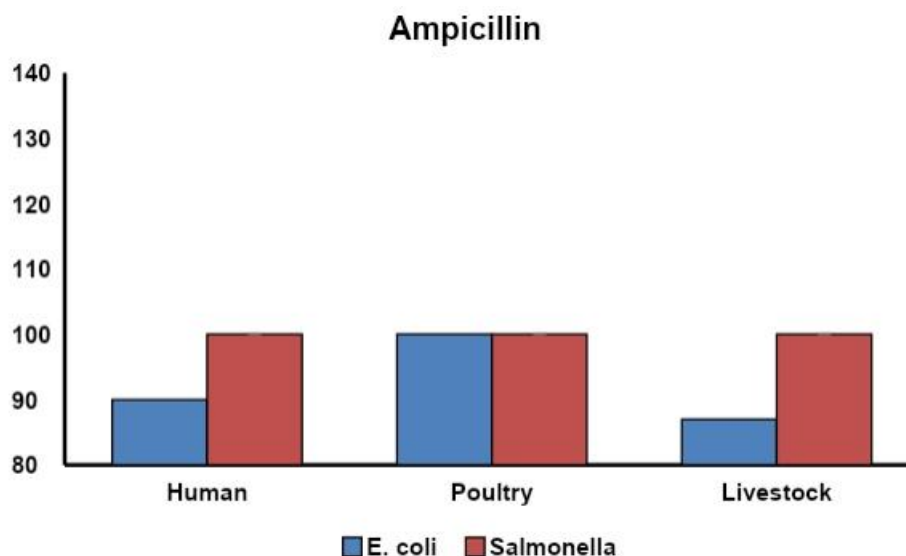


Fig. 1: Pattern of ampicillin resistance in Bangladesh

Amoxicillin found 74% to 100% resistant to *E. coli* and 16% to 100% resistant to *Salmonella* from human, poultry, and dairy samples in Bangladesh. Wu et al. [75] reported 85% amoxicillin resistance to *E. coli* from neonates in China. Abbassi et al. [76] showed 57% amoxicillin resistance to *E. coli* from livestock in

Tunisia, whereas 95% in diarrheic calves in Chile [77]. On the other hand, Garbaj et al. [78] found 100% *Salmonella* resistant amoxicillin from dairy products in Libya. Figure 2 represents resistance of amoxicillin to *E. coli* and *Salmonella*, whereas 100% resistance was noticed in both *E. coli* and *Salmonella* in poultry in Bangladesh. Similarly, Amoxicillin resistance in livestock was also significantly high. Long-term use of penicillin drugs in humans and animal therapeutics may result in higher detection of resistance against *E. coli* and *Salmonella* spp.

**Table 2. Resistance pattern of similar antibiotics used for *E. coli* and *Salmonella* spp. in Bangladesh.**

Antibiotic Class	Name of Antibiotics	Resistant Percentage for <i>E. coli</i>			References	Resistant Percentage for <i>Salmonella</i> spp.			References
		Human	Poultry	Livestock		Human	Poultry	Livestock	
Penicillins	Ampicillin	90	100	87	[18-22, 24-26]	100	100	100	[44-47]
	Amoxicillin	74	100	90	[18, 21, 23, 26]	16	100	100	[18, 48-50]
Cephalosporins	Cephalexin	84.1	100	53.8	[17, 23, 27]	06	65	71.4	[17, 18, 51]
	Ceftriaxone	63	69.24	21.79	[18, 28, 29]	03	96.42	33	[18, 52, 53]
Quinolones	Ciprofloxacin	61	100	22.1	[18, 28, 30, 31]	94	100	31.57	[18, 54, 55]
	Levofloxacin	54.3	81.6	14.8	[18, 31, 32]	25	50	9.1	[53, 56, 57]
	Norfloxacin	39	50	16.32	[24, 33, 34]	23	20	21.42	[18, 51, 58]
	Nalidixic Acid	85.9	100	86	[16, 20, 26, 35]	100	100	100	[44, 45, 59-62]
Aminoglycosides	Gentamicin	30	100	100	[18, 23, 36]	02	86.70	6.62	[4, 18, 54]
Macrolides	Erythromycin	98	100	88.89	[4, 22, 23, 37, 38]	87	100	100	[39, 45, 50, 55, 59, 63-65]
	Azithromycin	49	76.93	100	[4, 28, 33]	100	81.25	100	[4, 45, 60]
Tetracyclines	Tetracycline	56	100	89.44	[4, 18, 19, 37, 38]	15	100	86.76	[4, 18, 39, 48, 51, 59, 64, 66]
Phenicols	Doxycycline	61.1	78.1	28.57	[16, 32, 39]	7	79.31	26.66	[18, 61, 65]
	Chloramphenicol	40	97.2	33.89	[4, 24, 33]	20.8	94.28	76	[16, 47, 67]
Sulphonamides and Trimethoprim	Sulphamethoxazole-trimethoprim	78.1	100	100	[17, 20, 37, 41]	29.4	76.83	81.48	[3, 16, 19, 68]
Polymyxins	Colistin	2.9	48.84	15.9	[3, 27, 42]	19.54	60	89.47	[46, 55, 69]

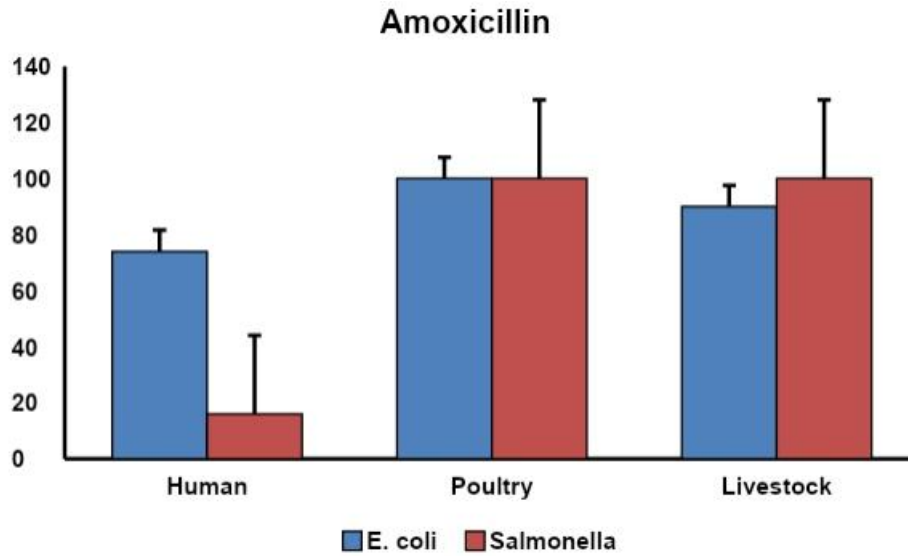


Fig. 2: Pattern of amoxicillin resistance in Bangladesh

### 5.2 Resistance to cephalosporins

Cephalexin is the first generation and ceftriaxone is the third generation cephalosporin, which are widely used to treat numerous diseases of humans, poultry, and livestock [16,17]. In this review, we found 53.8% to 100% cephalaxin resistant and 21.79% to 69.24% ceftriaxone resistance were observed in *E. coli* samples from humans, poultry, and ruminants. Recently, Eezzeldin et al. [79] reported 90.6% cephalaxin and 72% ceftriaxone resistance to *E. coli* from soba hospital samples in Sudan. On the other hand, Manishimwe et al. [80] found 56.8% ceftriaxone resistance to *E. coli* samples from dairy cattle in the USA. Figure 3 represents resistance of cephalaxin to *E. coli* and *Salmonella*, where 100% resistance was observed in salmonellosis in poultry in Bangladesh. In humans, 84.1% of cephalaxin-resistant *E. coli* was also alarming.

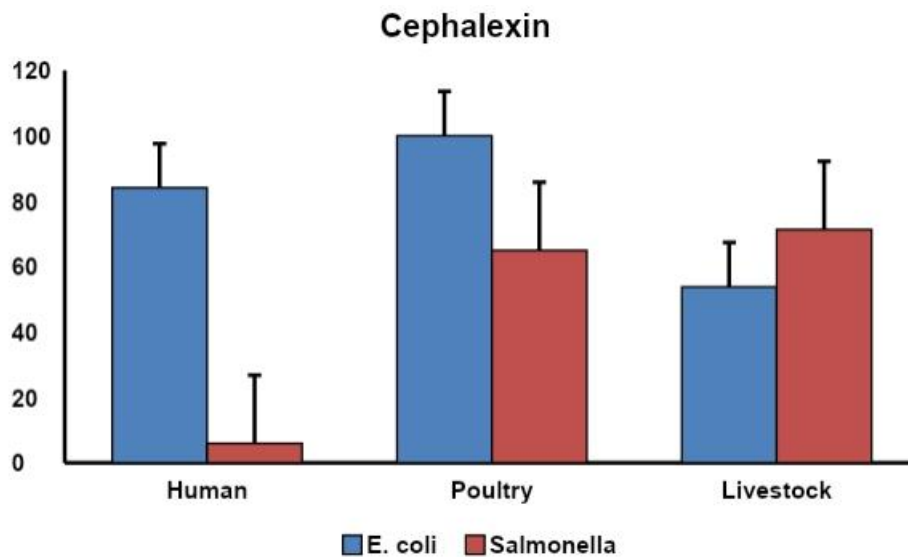


Fig. 3: Pattern of cephalaxin resistance in Bangladesh

About 6% to 71.4% cephalexin resistance and 3% to 96.42% ceftriaxone resistance were found against salmonellosis in humans and animals in Bangladesh. Elmadiena et al. [74] found 50% cephalexin resistant to *Salmonella* from humans and animals in Sudan. On the other hand, Oneko et al. [81] reported 56.5% ceftriaxone resistant against *Salmonella* in Kenya. Figure 4 represents resistance of ceftriaxone to *E. coli* and *Salmonella*, where highest resistance was noticed in salmonellosis in poultry in Bangladesh. These results highlight the urgent requirement for an improved drug monitoring system in Bangladesh.

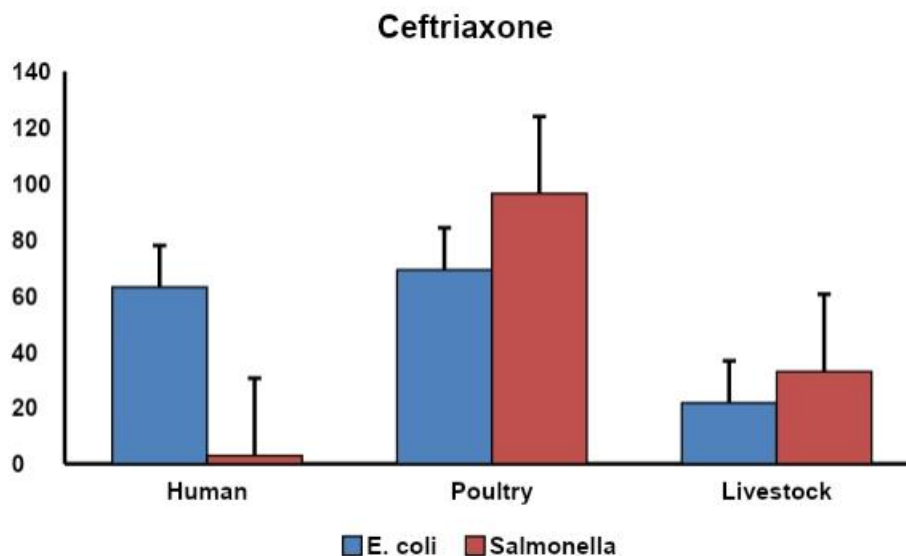
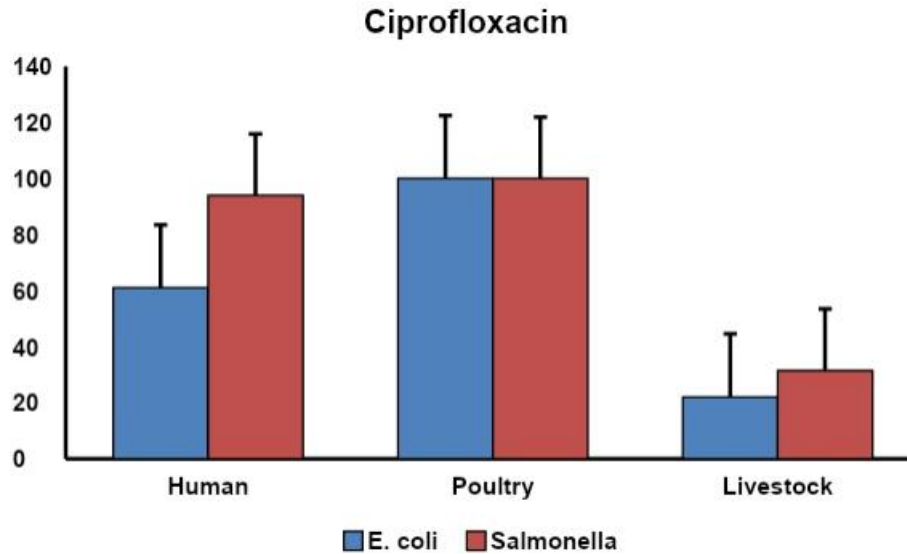


Fig. 4: Pattern of ceftriaxone resistance in Bangladesh

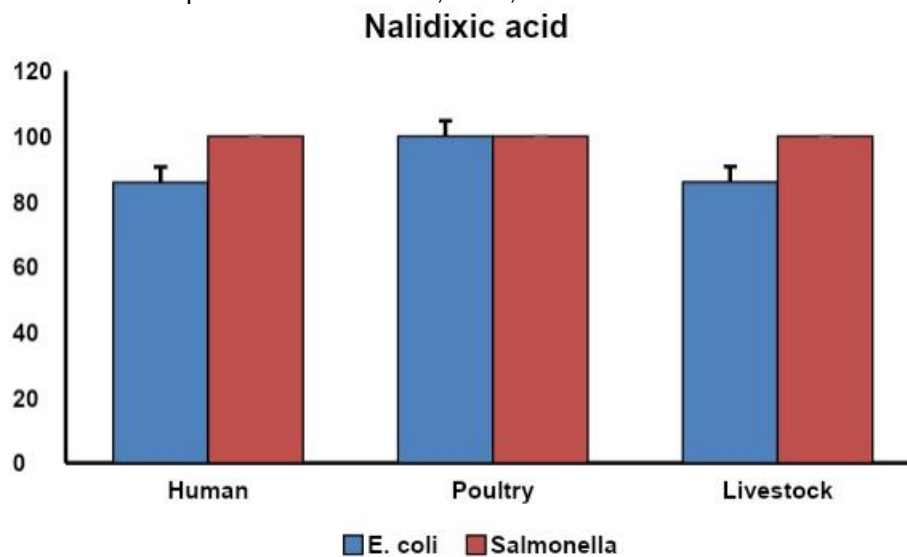
### 5.3 Resistance to Quinolones

Quinolone a class of antibiotics that is widely used for the treatment of bacterial infections. Fluoroquinolone antimicrobials like ciprofloxacin, levofloxacin, norfloxacin, and nalidixic acid are often used to treat a variety of illnesses in people, poultry, and animals [2]. In this study, we observed 22.1% to 100% ciprofloxacin resistance to *E. coli* and 31.57% to 100% ciprofloxacin resistance to *Salmonella* in humans, poultry, and livestock in Bangladesh. Recently, Eezzeldin et al. [79], Koju et al. [82], and Samy et al. [83] found 68%, 66%, and 50.8% resistance to ciprofloxacin against *E. coli* from humans, poultry, and livestock samples in Sudan, Nepal, and Egypt, respectively. *Salmonella* found 75% ciprofloxacin resistant from human and broiler isolates in Colombia [84]. Qamar et al. [85] reported 31% ciprofloxacin resistance from raw milk samples in Pakistan. Figure 5 shows resistance of ciprofloxacin to *E. coli* and *Salmonella*, where 100% resistance was noticed in both *E. coli* and *Salmonella* in poultry in Bangladesh. In humans, 94% of ciprofloxacin-resistant *Salmonella* detection was also significant.



**Fig. 5: Pattern of ciprofloxacin resistance in Bangladesh**

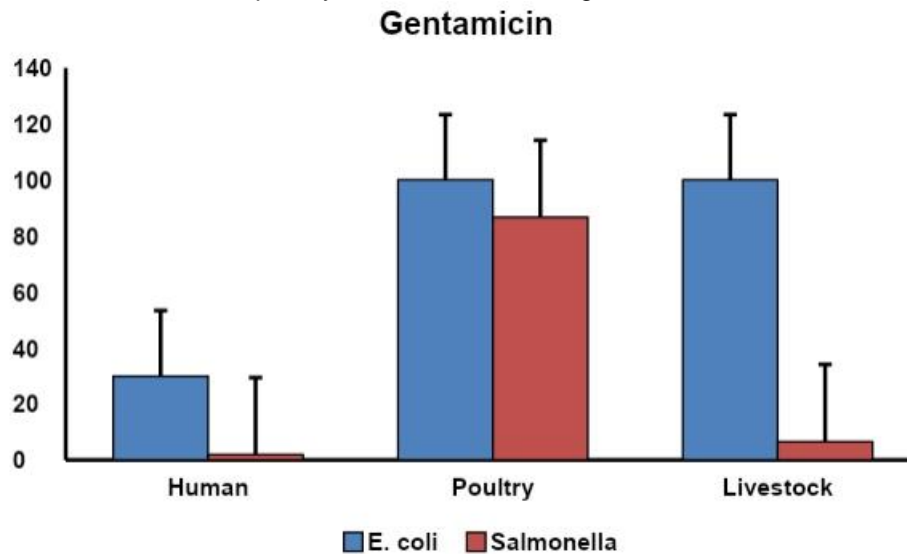
Levofloxacin found 54.3%, 81.6%, and 14.8% resistant to *E. coli*, whereas norfloxacin observed 39%, 50%, and 16.32% resistant to *E. coli* from human, poultry, and livestock samples in Bangladesh. In Colombia, Herrera-Sánchez et al. [84] found 57.1% levofloxacin-resistant *Salmonella* in human and broiler isolates. Nalidixic acid (NA) is another kind of quinolone antibiotic which is generally used to treat infections. In this study, we found 86% to 100% NA resistance to *E. coli* and *Salmonella* from various isolates of humans, poultry, and animals. Vuthy et al. [86] reported 91% *E. coli* resistant and 92% *Salmonella* spp. resistant NA from chicken samples in Cambodia. On the other hand, 77.3% of NA-resistant *E. coli* detected from fecal isolates of dairy cattle in Texas [80]. Figure 6 shows resistance of NA to *E. coli* and *Salmonella*, where 100% resistance was observed in the case of *Salmonella* among humans, poultry, and livestock in Bangladesh. These findings should serve as a warning regarding the rigorous application of fluoroquinolones in humans, birds, and animals.



**Fig. 6: Pattern of nalidixic acid resistance in Bangladesh**

#### 5.4 Resistance to Aminoglycosides

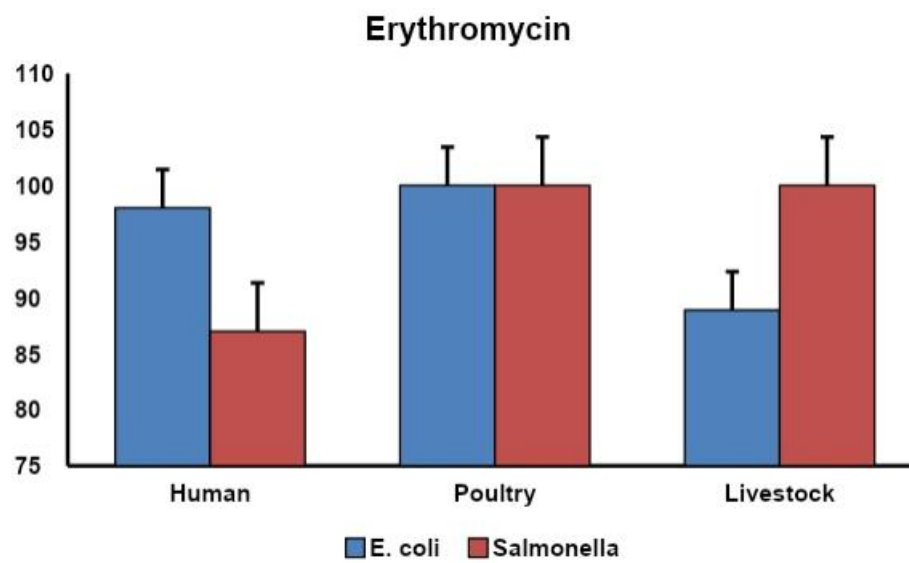
Aminoglycoside antibiotics inhibit the production of bacterial protein [87]. One of the most common aminoglycoside antibiotics used in human and animal medicine is gentamicin. In this study, we observed 30% to 100% gentamicin resistant to *E. coli* and 2% to 86.70% resistant to *Salmonella* from human, poultry, and livestock samples in Bangladesh. Recently, García-Béjar et al. [88] observed 79% resistance to gentamicin from *E. coli* samples in chicken samples in Spain. Abdelwahab et al. [73] also reported 85% resistance to gentamicin from *E. coli* isolates from ruminants in the UAE. In Pakistan, Wajid et al. [89] reported 64.70% gentamicin-resistant *S. Typhimurium* from poultry. The detection of higher resistance to gentamicin from animal samples is quite alarming. So, strict use of gentamicin for poultry production should be followed. Figure 7 represents resistance of gentamicin to *E. coli* and *Salmonella*, where higher resistance was noticed in *E. coli* in poultry and livestock in Bangladesh.



**Fig. 7: Pattern of gentamicin resistance in Bangladesh**

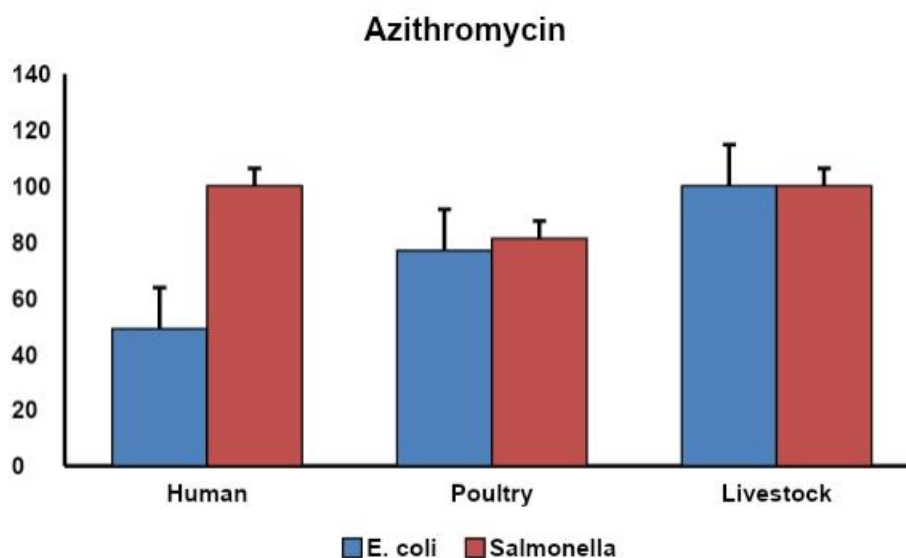
### 5.5 Resistance to Macrolides

Erythromycin and azithromycin are grouped into macrolides, where their main function is to restrict or inhibit bacterial growth rather than destroy it [90]. In Bangladesh, 88.89% to 100% erythromycin-resistant *E. coli* and 87% to 100% erythromycin-resistant *Salmonella* were observed from human, poultry, and livestock isolates. Kibret et al. [91] found 89.4% resistance to erythromycin against *E. coli* from human isolates in Ethiopia. Recently, Ranasinghe et al. [92] also reported 80.84% resistance of *E. coli* to erythromycin from poultry samples in Sri Lanka. Ramatla et al. [93] observed 89.3% erythromycin-resistant *Salmonella* from human and livestock isolates in South Africa. Sharma et al. [94] and Cardoso et al. [95] also noticed 100% resistant to *Salmonella* against erythromycin in India and Brazil, respectively. Adzitey et al. [96] found 86% erythromycin-resistant *Salmonella* from dairy cattle in Ghana. Figure 8 represents resistance of erythromycin to *E. coli* and *Salmonella*, where higher resistance was observed in all cases of humans, poultry, and livestock.



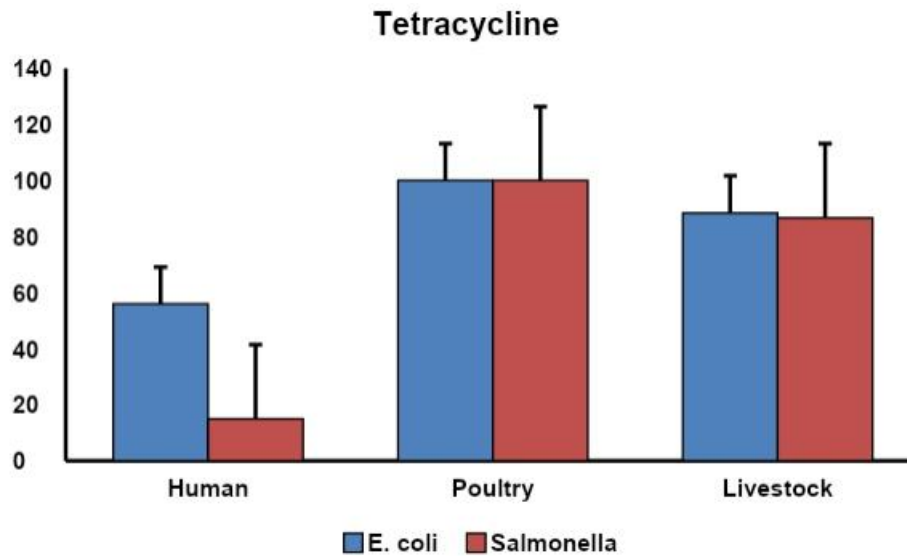
**Fig. 8: Pattern of erythromycin resistance in Bangladesh**

In this study, we found 49% to 100% azithromycin-resistant *E. coli* and 81.25% to 100% azithromycin-resistant *Salmonella* isolates from human and animal samples. Xiang et al. [97] reported 86.7% azithromycin-resistant *E. coli* from hospital patients samples in China. On the other hand, Gupta et al. [98] also found 73.3% azithromycin-resistant *Salmonella* from human isolates in India. Figure 9 represents resistance of azithromycin to *E. coli* and *Salmonella*, where 100% resistance was noticed in both *E. coli* and *Salmonella* in livestock.

**Fig. 9: Pattern of azithromycin resistance in Bangladesh**

### 5.6 Resistance to Tetracyclines

Tetracycline and doxycycline are grouped in tetracyclines that are often used in human-animal medicine. In Bangladesh, 56% to 100% tetracycline-resistant *E. coli* and 15% to 100% tetracycline-resistant *Salmonella* were observed in humans, poultry, and ruminants. Wilkerson et al. [99] reported 52% and 98% tetracycline-resistant *E. coli* from human and bovine isolates, respectively. Koju et al. [82] also found 87.7% tetracycline-resistant *E. coli* from chicken samples in Nepal. On the other hand, Pavelquesi et al. [100] reported 70% tetracycline-resistant *Salmonella* in human and animal origin. Sharma et al. [94] also detected 100% resistance tetracycline-resistant *Salmonella* from chicken meat samples in India. Figure 10 shows resistance of tetracycline to *E. coli* and *Salmonella*, where 100% resistance was noticed in both *E. coli* and *Salmonella* in poultry. Livestock also remained in the upper position.

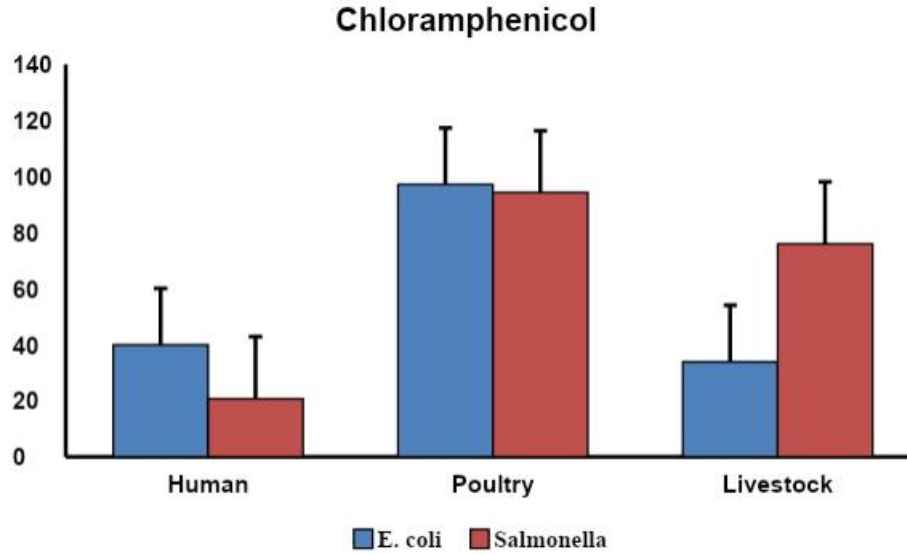


**Fig. 10: Pattern of tetracycline resistance in Bangladesh**

In this study, we found that more than 75% *E. coli* and *Salmonella* spp. isolated from poultry in Bangladesh were resistant to doxycycline. Racewicz [72] and Waghmare et al. [101] also reported *E. coli* and *Salmonella* as 100% resistant to doxycycline in China and India.

### 5.7 Resistance to Phenicol

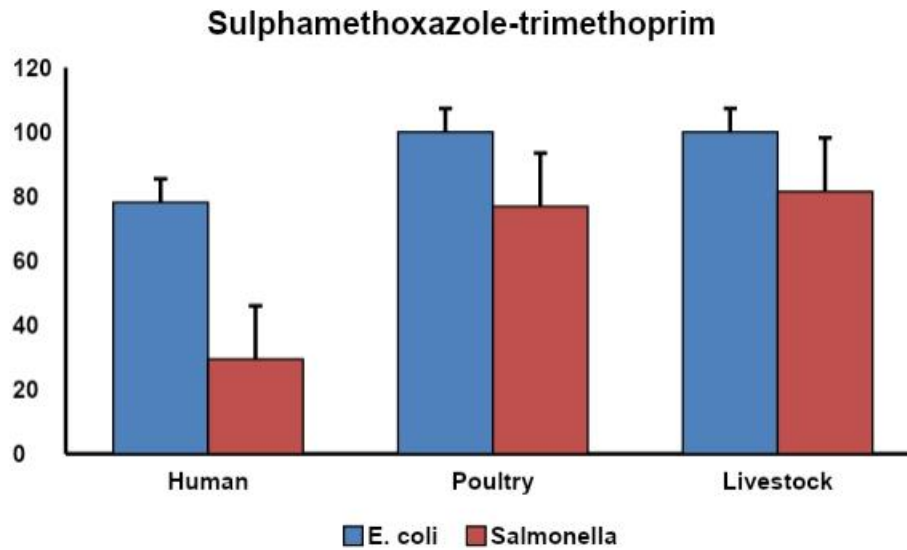
Chloramphenicol is not presently used widely but sometimes used in a lower dose, which may be harmful to the hosts [102]. But it has long been used to treat a variety of bacterial illnesses in people and animals [2]. In this review, we found 33.89% to 97.2% chloramphenicol-resistant *E. coli* and 20.8% to 94.28% chloramphenicol-resistant *Salmonella* from human, chicken, and livestock samples in Bangladesh. Abbasi et al. [76] reported 53.4% chloramphenicol-resistant *E. coli* from livestock samples in Tunisia. Okoli et al. [103] also found 100% chloramphenicol-resistant *E. coli* from poultry isolates in Nigeria. Busani et al. [104] found 84% and El-Sharkawy et al. [105] reported 100% resistant to chloramphenicol against *Salmonella* from cattle and poultry isolates in Italy and Egypt, respectively. Figure 11 shows resistance of tetracycline to *E. coli* and *Salmonella*, where 100% resistance was noticed in both *E. coli* and *Salmonella* in poultry.



**Fig. 11: Pattern of chloramphenicol resistance in Bangladesh**

### 5.8 Resistance to Sulphonamides

The sulfamethoxazole component is a member of the sulfonamide drug class that acts as a bacteriostatic [2]. In this study, we observed 78.1% to 100% sulphamethoxazole-trimethoprim resistance in *E. coli* and 29.4% to 81.48% sulphamethoxazole-trimethoprim resistance in *Salmonella* from human, poultry, and livestock sample in Bangladesh. Bailey et al. [106] reported 71% sulphamethoxazole-trimethoprim resistant *E. coli* from hospital patient samples in the USA. Racewicz et al. [72] also reported 84% resistance of *E. coli* to sulfamethoxazole-trimethoprim from poultry samples in China. On the other hand, Nguyen et al. [107] detected 53.04% sulphamethoxazole-trimethoprim resistant *Salmonella* from poultry isolates in Vietnam. Dahshan et al. [108] also reported 100% sulphamethoxazole-trimethoprim resistant *Salmonella* from pigs in Japan. Figure 12 shows resistance of sulphamethoxazole-trimethoprim to *E. coli* and *Salmonella*, where higher resistance was noticed in both *E. coli* and *Salmonella* in poultry and livestock.



**Fig. 12: Pattern of sulphamethoxazole-trimethoprim resistance in Bangladesh**

## 5. 9 Resistance to Polymyxins

Colistin is a polymyxin antibiotic that is restricted in application for the cure of human illness, but it is still widely used in animal production [2, 109]. In Bangladesh, 2.9% to 48.84% colistin-resistant *E. coli* and 19.54% to 89.47% colistin-resistant *Salmonella* were observed from human and animals isolates. Similarly, García-Béjar et al. [88] and Hess et al. [110] also reported 73.68% and 87% resistant to colistin against *E. coli* from poultry isolates in Spain and Austria respectively. Phiri et al. [111] also found 78.70% Colistin-resistant *Salmonella* in Zambia. Figure 13 shows resistance of colistin to *E. coli* and *Salmonella*, where higher resistance was observed in *E. coli* in livestock.

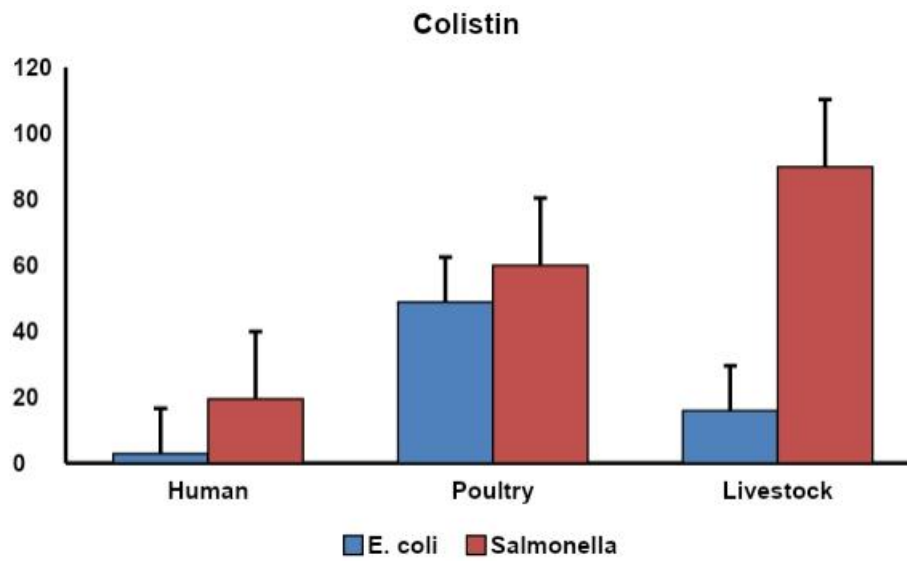


Fig. 13: Pattern of colistin resistance in Bangladesh

## 6. PREVENTION AND CONTROL MEASURES FOR *E. COLI* AND *SALMONELLA* SPP.

Antimicrobial resistance of *E. coli* and *Salmonella* spp. has a significant economic impact on every continent. It causes extra treatment expenses, loss of productivity, and death, all of which result in financial losses. Good personal hygiene, proper food handling, avoiding cross contamination of foods, and biosecurity system at farm level may reduce the clinical manifestation of diseases. Good cleanliness and an effective AMR surveillance system are essential to combat zoonotic infections and control *E. coli* and *Salmonella* infections. A national AMR monitoring system and strict use of antibiotics with proper management may also be helpful to reduce the growth of AMR.

## 7. CONCLUSION

Antimicrobial resistance is a critical issue that is increasing day by day. *E. coli* and *Salmonella* spp. have zoonotic significance, and AMR resistance genes may transfer through human and animal interactions. Penicillins, cephalosporins, quinolones, aminoglycosides, macrolides, tetracyclines, phenicols, sulphonamides, and polymyxins are different classes of antibiotics which were found to have higher resistance in this study. A similar group of antibiotics discovered resistance in humans, poultry, and livestock, which is extremely concerning for future AMR combat. Prevention and control measures with one health strategy may help reduce the risk of AMR transmission.

## REFERENCES

1. Murray CJ, Ikuta KS, Sharara F, Swetschinski L, Aguilar GR, Gray A et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*. 2022;399(10325):629-55. [https://doi.org/10.1016/s0140-6736\(22\)00947-3](https://doi.org/10.1016/s0140-6736(22)00947-3)
2. Hossain MJ, Attia Y, Ballah FM, Islam MS, Sobur MA, Islam MA et al. Zoonotic significance and antimicrobial resistance in *Salmonella* in poultry in Bangladesh for the period of 2011–2021. *Zoonotic Dis*. 2021;1(1):3-24. <https://doi.org/10.3390/zoonoticdis1010002>
3. Hossain MJ, Islam MS, Sobur MA, Zaman SB, Nahar A, Rahman M et al. Exploring poultry farm environment for antibiotic resistant *Escherichia coli*, *Salmonella* spp., and *Staphylococcus* spp. having public health significance. *J Bangladesh Agril Univ*. 2020;18(3): 615–622. <https://doi.org/10.5455/JBAU.98074>
4. Sobur MA, Sabuj AA, Sarker R, Rahman AT, Kabir SL, Rahman MT. Antibiotic-resistant *Escherichia coli* and *Salmonella* spp. associated with dairy cattle and farm environment having public health significance. *Vet World*. 2019;12(7):984. <https://doi.org/10.14202/vetworld.2019.984-993>
5. Bengtsson-Palme J, Kristiansson E, Larsson DJ. Environmental factors influencing the development and spread of antibiotic resistance. *FEMS Microb Revi*. 2018;42(1):fux053. <https://doi.org/10.1093/femsre/fux053>
6. Aranda CM, Arias CA, Tejada CE, Forde C, Park B, Rossi F et al. Scientific evidence for the control of antimicrobial resistance. *Revista Pana de Salud Pública*. 2020;44:e128. <https://doi.org/10.26633/rpsp.2020.128>
7. World Health Organization. Strategic and technical advisory group on antimicrobial resistance (STAG-AMR): report of the seventh meeting, 2-3 November 2016, WHO Headquarters, Geneva. World Health Organization; 2017. Accessed 3 November 2022. Available: <https://apps.who.int/iris/bitstream/handle/10665/255180/WHO-DGO-AMR-2017.1-eng.pdf>
8. Rosen T. Antibiotic resistance: an editorial review with recommendations. *J drugs dermatology*. 2011;10(7):724-33.
9. Rahman SMM, Hossain SM, Amin, MR. Antimicrobial Resistance: An Emerging Challenge in Public Health and Beyond. *Bangla Medical Res Counc Bull*. 2021;47(2). <https://doi.org/10.3329/bmrcb.v47i2.57766>
10. Orubu ES, Samad MA, Rahman MT, Zaman MH, Wirtz VJ. Mapping the Antimicrobial Supply Chain in Bangladesh: A Scoping-Review-Based Ecological Assessment Approach. *Glob Hea Sci Prac*. 2021;9(3):532-47. <https://doi.org/10.9745/ghsp-d-20-00502>
11. Holmes KK, Bertozzi S, Bloom BR, Jha P, Gelband H, DeMaria LM et al. Major Infectious Diseases: Key Messages from Disease Control Priorities, Third Edition. Review from The International Bank for Reconstruction and Development / The World Bank, Washington (DC); 2018.
12. *Salmonella*. CDC. Accessed 3 November 2022. Available: <https://www.cdc.gov/salmonella/index.htmlinfection>
13. *Salmonella* (non-typhoidal). WHO. Accessed 3 November 2022. Available: [https://www.who.int/news-room/fact-sheets/detail/salmonella-\(non-typhoidal\)](https://www.who.int/news-room/fact-sheets/detail/salmonella-(non-typhoidal))
14. Infection with *Salmonella*. CDC. Accessed 3 November 2022. Available: [https://www.cdc.gov/training/SIC\\_CaseStudy/Infection\\_Salmonella\\_ptversion.pdf](https://www.cdc.gov/training/SIC_CaseStudy/Infection_Salmonella_ptversion.pdf)
15. Antibiotics. Accessed 3 November 2022. Available: <https://medlineplus.gov/antibiotics.html>

16. Ahmed I, Rabbi MB, Sultana S. Antibiotic resistance in Bangladesh: A systematic review. *International J Infect Dis.* 2019;80:54-61. <https://doi.org/10.1016/j.ijid.2018.12.017>
17. Al Amin M, Hoque MN, Siddiki AZ, Saha S, Kamal MM. Antimicrobial resistance situation in animal health of Bangladesh. *Vet World.* 2020;13(12):2713. <https://doi.org/10.14202/vetworld.2020.2713-2727>
18. Update of AMR Surveillance in Bangladesh (2016-2021). IEDCR. Accessed 3 November 2022. Available: [https://old.iedcr.gov.bd/website/images/files/AMR/Presentation%20on%20Update%20of%20AMR%20Surveillance%20in%20Bangladesh%20\(2016-2021\).pdf](https://old.iedcr.gov.bd/website/images/files/AMR/Presentation%20on%20Update%20of%20AMR%20Surveillance%20in%20Bangladesh%20(2016-2021).pdf)
19. Sarker MS, Mannan MS, Ali MY, Bayzid M, Ahad A, Bupasha ZB. Antibiotic resistance of *Escherichia coli* isolated from broilers sold at live bird markets in Chattogram, Bangladesh. *JAVAR.* 2019;6(3):272. <https://doi.org/10.5455/javar.2019.f344>
20. Bashar T, Rahman M, Rabbi FA, Noor R, Rahman MM. Enterotoxin profiling and antibiogram of *Escherichia coli* isolated from poultry feces in Dhaka district of Bangladesh. *Stam J Micro.* 2011;1(1):51-7. <https://doi.org/10.3329/sjm.v1i1.9134>
21. AK PM, Marzan M, Liza SM, Mou TJ, Azmi IJ. Prevalence of inhibitor resistant beta lactamase producing *E. coli* in human and poultry origin of Bangladesh. *J Bacteriol Parasitol.* 2016;7(271):2. <https://doi.org/10.4172/2155-9597.1000271>
22. Runa JA, Lijon MB, Rahman MA. Detection of multidrug resistant and shiga toxin producing *Escherichia coli* (STEC) from apparently healthy broilers in Jessore, Bangladesh. *Frontiers Environ Microb.* 2018;4(1):16-21. <https://doi.org/10.11648/j.fem.20180401.13>
23. Khatun MN, Mahbub-E-Elahi AT, Ahmed S, Parvej MS, Akhter S, Ansari WK et al. Frequency of drug resistant *Escherichia coli* isolated from commercial broiler chicken in Bangladesh. *Int J Nat Soc Sci.* 2015;2:01-5.
24. Levy S, Islam MS, Sobur MA, Talukder M, Rahman MB, Khan MF et al. Molecular detection of avian pathogenic *Escherichia coli* (APEC) for the first time in layer farms in Bangladesh and their antibiotic resistance patterns. *Microorganisms.* 2020;8(7):1021. <https://doi.org/10.3390/microorganisms8071021>
25. Haque MH, Rahman MM, Miah ML, Ahmed S, Sazib MR, Khaton R et al. Exploring Antibiotic Resistance Pattern of *Escherichia coli*, *Salmonella* spp., and *Staphylococcus* spp. Isolated from Eggs in Rajshahi. *European J Agri Food Sci.* 2021;3(4):25-30. <https://doi.org/10.24018/ejfood.2021.3.4.328>
26. Gupta MD, Islam M, Sen A, Sarker MS, Das A. Prevalence and antibiotic susceptibility pattern of *Escherichia coli* in cattle on Bathan and intensive rearing system. *Microb Hea.* 2017;6(1):1-4. <https://doi.org/10.3329/mh.v6i1.34062>
27. Hossain A, Hossain SA, Fatema AN, Wahab A, Alam MM, Islam MN et al. Age and gender-specific antibiotic resistance patterns among Bangladeshi patients with urinary tract infection caused by *Escherichia coli*. *Heliyon.* 2020;6(6):e04161. <https://doi.org/10.1016/j.heliyon.2020.e04161>
28. Rahman MA, Ahmed MS. Antibiogram of *E. coli* and *Salmonella* spp. isolated from chicken meat and frozen milk in Barishal city, Bangladesh. *BJVM.* 2022;20(1):AMRT1- AMRT1. <https://doi.org/10.33109/bjvmjj2022amrt1>
29. Islam K, Ahad A, Barua M, Islam A, Chakma S, Dorji C et al. Isolation and epidemiology of multidrug resistant *Escherichia coli* from goats in Cox s Bazar, Bangladesh. *JAVAR.* 2016;3(2):166-72. <https://doi.org/10.5455/javar.2016.c147>
30. Hassan MM, Amin KB, Ahaduzzaman M, Alam M, Faruk MS, Uddin I. Antimicrobial resistance pattern against *E. coli* and *Salmonella* in layer poultry. *Res. J. Vet. Pract.* 2014;2(2):30-5. <https://doi.org/10.14737/journal.rjvp/2014/2.2.30.35>
31. Mamun M, Hassan J, Nazir KH, Islam A, Zesmin K, Rahman B et al. Prevalence and molecular detection of quinolone-resistant *E. coli* in rectal swab of apparently healthy cattle in Bangladesh. *Int J Trop Dis Health.* 2017;24(2):1-7. <https://doi.org/10.9734/ijtdh/2017/34404>
32. Mandal AK, Talukder S, Hasan MM, Tasmim ST, Parvin MS, Ali MY et al. Epidemiology and antimicrobial resistance of *Escherichia coli* in broiler chickens, farmworkers, and farm sewage in Bangladesh. *Vet Med Sci.* 2022;8(1):187-99. <https://doi.org/10.1002/vms3.664>
33. Jain P, Bepari AK, Sen PK, Rafe T, Imtiaz R, Hossain M et al. High prevalence of multiple antibiotic resistance in clinical *E. coli* isolates from Bangladesh and prediction of molecular

- resistance determinants using WGS of an XDR isolate. *Sci Reports*. 2021;11(1):1-3. <https://doi.org/10.1038/s41598-021-02251-w>
34. Hossain MK, Rahman M, Nahar A, Khair A, Alam MM. Isolation and identification of diarrheagenic *Escherichia coli* causing colibacillosis in calf in selective areas of Bangladesh. *BJVM*. 2013;11(2):145-9. <https://doi.org/10.3329/bjvm.v11i2.19139>
  35. Hossain MT, Siddique MP, Hossain FM, Zinnah MA, Hossain MM, Alam MK et al. Isolation, identification, toxin profile and antibiogram of *Escherichia coli* isolated from broilers and layers in Mymensingh district of Bangladesh. *BJVM*. 2008;6(1):1-5. <https://doi.org/10.3329/bjvm.v6i1.1330>
  36. Rahman MT, Islam MS, Hasan M. Isolation and identification of bacterial agents causing clinical mastitis in Cattle in Mymensingh and their antibiogram Profile. *Microb Hea*. 2013;2(1):19-21. <https://doi.org/10.3329/mh.v2i1.17258>
  37. Nobel F, Akter S, Jebin RA, Sarker TC, Mizanur M, Rahman SA et al. Prevalence of multidrug resistance patterns of *Escherichia coli* from suspected urinary tract infection in Mymensingh city, Bangladesh. *J Adv Biotechnol Exp Ther*. 2021;4:256. <https://doi.org/10.5455/jabet.2021.d126>
  38. Al Azad MA, Rahman MM, Amin R, Begum MI, Fries R, Husna A et al. Susceptibility and multidrug resistance patterns of *Escherichia coli* isolated from cloacal swabs of live broiler chickens in Bangladesh. *Pathogens*. 2019;8(3):118. <https://doi.org/10.3390/pathogens8030118>
  39. Tawyabur M, Islam MS, Sobur MA, Hossain MJ, Mahmud MM, Paul S et al. Isolation and characterization of multidrug-resistant *Escherichia coli* and *Salmonella* spp. from healthy and diseased turkeys. *Antibiotics*. 2020;9(11):770. <https://doi.org/10.3390/antibiotics9110770>
  40. Rahman MA, Rahman AK, Islam MA, Alam MM. Antimicrobial resistance of *Escherichia coli* isolated from milk, beef and chicken meat in Bangladesh. *BJVM*. 2017;15(2):141-6. <https://doi.org/10.3329/bjvm.v15i2.35525>
  41. Hashem MA, Elahi MF, Mannan MA, Kabir MHB, Kashem MA, Pallab MS. Isolation, identification and antibiogram of *Escherichia coli* from broiler at Chittagong district in Bangladesh. *Waya J Ani Sci*. 2012; 312-316.
  42. Dutta A, Islam MZ, Barua H, Rana EA, Jalal MS, Dhar PK et al. Acquisition of plasmid-mediated colistin resistance gene *mcr-1* in *Escherichia coli* of livestock origin in Bangladesh. *Microbial Drug Resistance*. 2020;26(9):1058-62. <https://doi.org/10.1089/mdr.2019.0304>
  43. Poirel L, Madec JY, Lupo A, Schink AK, Kieffer N, Nordmann P et al. Antimicrobial resistance in *Escherichia coli*. *Microb Spec*. 2018;6(4):6-4. <https://doi.org/10.1128/microbiolspec.arba-0026-2017>
  44. Akter L, Hassan M, Ahmed Z. Present status and antibiotic sensitivity pattern of *Salmonella typhi* and *S. paratyphi* in different age group hospitalized patients in Dhaka city, Bangladesh. *IOSR J Pharm Biol Sci*. 2012;4(3):27-30. <https://doi.org/10.9790/3008-0432730>
  45. Jahan F, Kabir SL, Amin MM. Identification and antimicrobial resistance profiles of *Salmonellae* isolated from the broiler dressing plants associated with their environments. *Adv Res J Microbio*. 2013; 1:1-9.
  46. Mahmud T, Hassan MM, Alam M, Khan MM, Bari MS, Islam A. Prevalence and multidrug-resistant pattern of *Salmonella* from the eggs and egg-storing trays of retail markets of Bangladesh. *Int J One Health*. 2016;2:7-11. <https://doi.org/10.14202/ijoh.2016.7-11>
  47. Abdullah M, Akter MR, Kabir SL, Khan MA, Abdulaziz M. Characterization of bacterial pathogens isolated from calf diarrhoea in Panchagarh district of Bangladesh. *J Agri Food Tech*. 2013;3(6):8-13.
  48. Hassan MM, Amin KB, Ahaduzzaman M, Alam M, Faruk MS, Uddin I. Antimicrobial resistance pattern against *E. coli* and *Salmonella* in layer poultry. *Res J Vet Pract*. 2014;2(2):30-5. <https://doi.org/10.14737/journal.rjvp/2014/2.2.30.35>
  49. Talukder M, Islam MS, Levy S, Sobur MA, Ballah FM, Najibullah M et al. Detection of multidrug resistant *Salmonella* spp. from healthy and diseased broilers having potential public health significance. *J Adv Biotechnol Exp Ther*. 2021;4(2):248-55. <https://doi.org/10.5455/jabet.2021.d125>
  50. Sabur MA, Das MR, Uddin MB, Rahman MM, Islam MR, Shahidur M et al. Molecular Detection and Antibiotic Sensitivity of *Salmonella* Species Isolated from Goat Feces in Sylhet District of Bangladesh. *World Vet J*. 2021;11(3):395-401. <https://doi.org/10.54203/scil.2021.wvj51>

51. Akond MA, Shirin M, Alam S, Hassan SM, Rahman MM, Hoq M. Frequency of drug resistant *Salmonella* spp. isolated from poultry samples in Bangladesh. *Stam J Microb.* 2012;2(1):15-9. <https://doi.org/10.3329/sjm.v2i1.15207>
52. Chaudhary P, Salam SA, Reza MA, Ahaduzzaman M. High prevalence of ciprofloxacin and ceftriaxone resistance *Salmonella* in the retail chicken market of Chattogram, Bangladesh. *Turkish J Vet Res.* 2019;3(2):51-5.
53. Hoque R, Ahmed SM, Naher N, Islam MA, Rousham EK, Islam BZ et al. Tackling antimicrobial resistance in Bangladesh: A scoping review of policy and practice in human, animal and environment sectors. *PloS One.* 2020;15(1):e0227947. <https://doi.org/10.1371/journal.pone.0227947>
54. Siddiky NA, Sarker MS, Khan MS, Begum R, Kabir ME, Karim MR et al. Virulence and antimicrobial resistance profiles of *Salmonella enterica* serovars isolated from chicken at wet markets in Dhaka, Bangladesh. *Microorganisms.* 2021;9(5):952. <https://doi.org/10.3390/microorganisms9050952>
55. Priitha ST, Rahman S, Punom SA, Rahman MM, Nazir KN, Islam MS. Isolation, Molecular Detection and Antibiogram of Multi-drug Resistant *Salmonella Typhimurium* DT104 from Selected Dairy Farms in Mymensingh, Bangladesh. *Ameri J Microb Res.* 2020;8(4):136-40.
56. Abedin MZ, Ahmed AA, Hossain MS, Aktar MB. Laboratory based diagnosis of bacteraemia among inpatients and outpatients with acute febrile illness at Khwaja Yunus Ali Medical College and Hospital in Bangladesh. *Eur J Med Health Sci.* 2020;2(3):46-51. <https://doi.org/10.34104/ejmhs.020.046051>
57. Sultana M, Bilkis R, Diba F, Hossain MA. Predominance of multidrug resistant zoonotic *Salmonella* Enteritidis genotypes in poultry of Bangladesh. *J Poult Sci.* 2014;0130222. <https://doi.org/10.2141/jpsa.0130222>
58. Sohidullah M, Khan MS, Islam MS, Islam MM, Rahman S, Begum F. Isolation, molecular identification and antibiogram profiles of *Escherichia coli* and *Salmonella* spp. from diarrhoeic cattle reared in selected areas of Bangladesh. *Asian J Med Bio Res.* 2016;2(4):587-95. <https://doi.org/10.3329/ajmbr.v2i4.31001>
59. Paul P, Akther S, Ali MZ, Banu H, Khan MS, Khatun MM. Isolation, identification and antibiogram study of *Salmonella* spp. from poultry farm environment. *Int J Anim Biol.* 2017;3(2):5-11.
60. Hossain MM, Jabin T, Hossain MI, Khatun MA, Emam MH, Asaduzzaman M et al. Antibiotic resistance profiling of clinical isolates of *Salmonella enterica* Serovar Paratyphi A in Dhaka, Bangladesh. *Stam J Micro.* 2021;11(1):14-6. <https://doi.org/10.3329/sjm.v11i1.57146>
61. Rana E. Antibiotic resistance, microbial and morphological changes of marketed bovine liver at different time interval from Chittagong, Bangladesh: A public health Concern. *Res Rev J Vet Sci.* 2017;3(1):16-23.
62. Sarker BR, Ghosh S, Chowdhury S, Dutta A, Chandra Deb L, Krishna Sarker B et al. Prevalence and antimicrobial susceptibility profiles of non-typhoidal *Salmonella* isolated from chickens in Rajshahi, Bangladesh. *Vet Med Sci.* 2021;7(3):820-30. <https://doi.org/10.1002/vms3.440/v2/response1>
63. Uddin MS, Hoq MI, Ali MS, Rahman MM, Islam KS. Antibiotic resistance pattern of *Salmonella* spp. isolated from stool samples of hospitalized diarrheal patients in Bangladesh. *Asian J Med Bio Res.* 2017;3(4):534-538. <https://doi.org/10.3329/ajmbr.v3i4.35346>
64. Mamun MA, Kabir SL, Islam MM, Lubna M, Islam SS, Akhter AT et al. Molecular identification and characterization of *Salmonella* species isolated from poultry value chains of Gazipur and Tangail districts of Bangladesh. *African J Micro Res.* 2017; 11:474–481. <https://doi.org/10.5897/ajmr2017-8431>
65. Rahman MA, Rahman AK, Islam MA, Alam MM. Detection of multi–drug resistant *Salmonella* from milk and meat in Bangladesh. *BJVM.* 2018;16(1):115-20. <https://doi.org/10.3329/bjvm.v16i1.37388>
66. Karim SJ, Islam M, Sikder T, Rubaya R, Halder J, Alam J. Multidrug-resistant *Escherichia coli* and *Salmonella* spp. isolated from pigeons. *Vet World.* 2020;13(10):2156. <https://doi.org/10.14202/vetworld.2020.2156-2165>
67. Alam SB, Mahmud M, Akter R, Hasan M, Sobur A, Nazir KN et al. Molecular detection of multidrug resistant *Salmonella* species isolated from broiler farm in Bangladesh. *Pathogens.* 2020;9(3):201. <https://doi.org/10.3390/pathogens9030201>

68. Uddin MB, Hossain SB, Hasan M, Alam MN, Debnath M, Begum R et al. Multidrug antimicrobial resistance and molecular detection of MCR-1 gene in *Salmonella* species isolated from chicken. *Animals*. 2021;11(1):206. <https://doi.org/10.3390/ani11010206>
69. Islam MB, Shahid SB, Satar AA, Yusuf MA, Islam S, Islam, R. Prevalence and Antibiotic Resistance Pattern of *Salmonella typhi* and *Salmonella paratyphi* A isolated by Automated Blood Culture System. *Bangla J Infect Dis*. 2020;7(2):57-60. <https://doi.org/10.3329/bjid.v7i2.51510>
70. Manhique-Coutinho L, Chiani P, Michelacci V, Taviani E, Bauhofer AFL, Chissaque A et al. Molecular characterization of diarrheagenic *Escherichia coli* isolates from children with diarrhea: A cross-sectional study in four provinces of Mozambique: Diarrheagenic *Escherichia coli* in Mozambique. *Inter J Infect Dis*. 2022;121:190-194. <https://doi.org/10.1016/j.ijid.2022.04.054>
71. Qin X, Yang M, Cai H, Liu Y, Gorris L, Aslam MZ et al. Antibiotic Resistance of *Salmonella* Typhimurium Monophasic Variant 1, 4,[5], 12: i:-in China: A Systematic Review and Meta-Analysis. *Antibiotics*. 2022;11(4):532. <https://doi.org/10.3390/antibiotics11040532>
72. Racewicz P, Majewski M, Biesiada H, Nowaczewski S, Wilczyński J, Wystalska D et al. Prevalence and characterisation of antimicrobial resistance genes and class 1 and 2 integrons in multiresistant *Escherichia coli* isolated from poultry production. *Sci Reports*. 2022;12(1):1-13. <https://doi.org/10.1038/s41598-022-09996-y>
73. Abdelwahab GE, Ishag HZ, Al Hammadi ZM, Al Yammahi SM, Mohd Yusof MF, Al Yassi MS et al. Antibiotics Resistance in *Escherichia coli* Isolated from Livestock in the Emirate of Abu Dhabi, UAE, 2014–2019. *Intern J Micro*. 2022;2022. <https://doi.org/10.1155/2022/3411560>
74. Elmadiena MM, El Hussein AA, Muckle CA, Cole L, Wilkie E, Mistry K et al. Antimicrobial susceptibility and multi-drug resistance of *Salmonella enterica* subspecies enterica serovars in Sudan. *Tropical Ani Heal Product*. 2013;45(5):1113-8. <https://doi.org/10.1007/s11250-012-0334-7>
75. Wu D, Ding Y, Yao K, Gao W, Wang Y. Antimicrobial resistance analysis of clinical *Escherichia coli* isolates in neonatal ward. *Front Pedia*. 2021;9:670470. <https://doi.org/10.3389/fped.2021.670470>
76. Abbassi MS, Kilani H, Zouari M, Mansouri R, El Fekih O, Hammami S et al. Antimicrobial resistance in *Escherichia coli* isolates from healthy poultry, bovine and ovine in Tunisia: a real animal and human health threat. *J Clin Micro Biochem Techno*. 2017;3(2):019-23. <https://doi.org/10.17352/jcmbt.000021>
77. Astorga F, Navarrete-Talloni MJ, Miró MP, Bravo V, Toro M, Blondel CJ et al. Antimicrobial resistance in *E. coli* isolated from dairy calves and bedding material. *Heliyon*. 2019;5(11):e02773. <https://doi.org/10.1016/j.heliyon.2019.e02773>
78. Garbaj AM, Gawella TB, Sherif JA, Naas HT, Eshamah HL, Azwai SM et al. Occurrence and antibiogram of multidrug-resistant *Salmonella enterica* isolated from dairy products in Libya. *Vet World*. 2022;15(5):1185. <https://doi.org/10.14202/vetworld.2022.1185-1190>
79. Eezzeldin HM, Badi S, Yousef, BA. The Antibiotic Resistance and Multidrug Resistance Pattern of Uropathogenic *Escherichia coli* at Soba University Hospital: A Descriptive Retrospective Survey. *Sudan J Med Sci*. 2022;17(1):56-69. <https://doi.org/10.18502/sjms.v17i1.10685>
80. Manishimwe R, Moncada PM, Bugarel M, Scott HM, Loneragan GH. Antibiotic resistance among *Escherichia coli* and *Salmonella* isolated from dairy cattle feces in Texas. *Plos One*. 2021;16(5):e0242390. <https://doi.org/10.1371/journal.pone.0242390>
81. Oneko M, Kariuki S, Muturi-Kioi V, Otieno K, Otieno VO, Williamson JM et al. Emergence of community-acquired, multidrug-resistant invasive nontyphoidal *Salmonella* disease in rural Western Kenya, 2009–2013. *Clin Infect Dis*. 2015;61(suppl\_4):S310-6. <https://doi.org/10.1093/cid/civ674>
82. Koju P, Shrestha R, Shrestha A, Tamrakar S, Rai A, Shrestha P et al. Antimicrobial Resistance in *E. coli* Isolated from Chicken Cecum Samples and Factors Contributing to Antimicrobial Resistance in Nepal. *Tropical Med Infect Dis*. 2022;7(9):249. <https://doi.org/10.3390/tropicalmed7090249>
83. Samy AA, Mansour AS, Khalaf DD, Khairy EA. Development of multidrug-resistant *Escherichia coli* in some Egyptian veterinary farms. *Vet World*. 2022;15(2):488. <https://doi.org/10.14202/vetworld.2022.488-495>
84. Herrera-Sánchez MP, Castro-Vargas RE, Fandiño-de-Rubio LC, Rodríguez-Hernández R, Rondón-Barragán IS. Molecular identification of fluoroquinolone resistance in *Salmonella* spp.

- isolated from broiler farms and human samples obtained from two regions in Colombia. *Vet World*. 2021;14(7):1767. <https://doi.org/10.14202/vetworld.2021.1767-1773>
85. Qamar A, Ismail T, Akhtar S. Prevalence and antibiotic resistance of *Salmonella* spp. in South Punjab-Pakistan. *Plos One*. 2020;15(11):e0232382. <https://doi.org/10.1371/journal.pone.0232382>
  86. Vuthy Y, Lay KS, Seiha H, Kerleguer A, Aidara-Kane A. Antibiotic susceptibility and molecular characterization of resistance genes among *Escherichia coli* and among *Salmonella* subsp. in chicken food chains. *Asian Paci J Trop Biomed*. 2017;7(7):670-4. <https://doi.org/10.1016/j.apjtb.2017.07.002>
  87. Mingeot-Leclercq MP, Glupczynski Y, Tulkens PM. Aminoglycosides: activity and resistance. *Antimicrob Age Chemothe*. 1999;43(4):727-37. <https://doi.org/10.1128/aac.43.4.727>
  88. García-Béjar B, García de Blas Martín I, Arévalo-Villena M, Briones Pérez A. High Prevalence of Antibiotic-Resistant *Escherichia coli* isolates from Retail Poultry Products in Spain. *Animals*. 2021;11(11):3197. <https://doi.org/10.3390/ani11113197>
  89. Wajid M, Awan AB, Saleemi MK, Weinreich J, Schierack P, Sarwar Y et al. Multiple drug resistance and virulence profiling of *Salmonella enterica* serovars Typhimurium and Enteritidis from poultry farms of Faisalabad, Pakistan. *Microb Drug Resis*. 2019;25(1):133-42. <https://doi.org/10.1089/mdr.2018.0121>
  90. Giguere S, Prescott JF, Baggot JD, Walker RD, Dowling PM. *Antimicrobial Therapy in Veterinary Medicine*, 4th ed. Wiley-Blackwell: New Jersey, USA, 2006; ISBN 978-0-8138-0656-3.
  91. Kibret M, Abera B. Antimicrobial susceptibility patterns of *E. coli* from clinical sources in northeast Ethiopia. *Afri Hea Sci*. 2011;11:40-5. <https://doi.org/10.4314/ahs.v11i3.70069>
  92. Ranasinghe RASS, Satharasinghe DA, Anwarama PS, Parakatawella PMSDK, Jayasooriya LJPAP, Ranasinghe RMSBK et al. Prevalence and Antimicrobial Resistance of *Escherichia coli* in Chicken Meat and Edible Poultry Organs Collected from Retail Shops and Supermarkets of North Western Province in Sri Lanka. *J Food Qua*. 2022;8962698:1-10. <https://doi.org/10.1155/2022/8962698>
  93. Ramatla T, Tawana M, Onyiche TE, Lekota KE, Thekisoe O. Prevalence of antibiotic resistance in *Salmonella* serotypes concurrently isolated from the environment, animals, and humans in South Africa: a systematic review and meta-analysis. *Antibiotics*. 2021;10(12):1435. <https://doi.org/10.3390/antibiotics10121435>
  94. Sharma J, Kumar D, Hussain S, Pathak A, Shukla M, Kumar VP et al. Prevalence, antimicrobial resistance and virulence genes characterization of nontyphoidal *Salmonella* isolated from retail chicken meat shops in Northern India. *Food Control*. 2019;102:104-11. <https://doi.org/10.1016/j.foodcont.2019.01.021>
  95. Cardoso MO, Ribeiro AR, Santos LR, Pilotto F, de Moraes HL, Salle CT et al. Resistência antimicrobiana em *Salmonella* Enteritidis isoladas de carcaças de frango. *Braz J Microb*. 2006;37:368-71.
  96. Adzitey F, Asiamah P, Boateng EF. Prevalence and antibiotic susceptibility of *Salmonella enterica* isolated from cow milk, milk products and hands of sellers in the Tamale Metropolis of Ghana. *J Appl Sci Environ Manage*. 2020;24(1):59-64. <https://doi.org/10.4314/jasem.v24i1.8>
  97. Xiang Y, Wu F, Chai Y, Xu X, Yang L, Tian S et al. A new plasmid carrying mphA causes prevalence of azithromycin resistance in enterotoxigenic *Escherichia coli* serogroup O6. *BMC Microbio*. 2020;20(1):1-9. <https://doi.org/10.1186/s12866-020-01927-z>
  98. Gupta R, Sarkar B, Sharma M, Choudhary S, Mahawar P. Increasing Azithromycin resistance *Salmonella* bacteremia in pediatric population in a secondary care center in India. *Int J Infect Dis*. 2020;101:74. <https://doi.org/10.1016/j.ijid.2020.09.222>
  99. Wilkerson C, Samadpour M, van Kirk N, Roberts MC. Antibiotic resistance and distribution of tetracycline resistance genes in *Escherichia coli* O157: H7 isolates from humans and bovines. *Antimicrob Age Chemothe*. 2004;48(3):1066-7. <https://doi.org/10.1128/aac.48.3.1066-1067.2004>
  100. Pavelquesi SLS, de Oliveira Ferreira ACA, Rodrigues ARM, de Souza Silva CM, Orsi, DC, da Silva ICR. Presence of tetracycline and sulfonamide resistance genes in *Salmonella* spp.: literature review. *Antibiotics*. 2021;10(11):1314. <https://doi.org/10.3390/antibiotics10111314>
  101. Waghmare RN, Paturkar AM, Vaidya VM, Zende RJ, Dubal ZN, Dwivedi A et al. Phenotypic and genotypic drug resistance profile of *Salmonella* serovars isolated from poultry farm and

- processing units located in and around Mumbai city, India. *Vet World*. 2018; 11(12):1682. <https://doi.org/10.14202/vetworld.2018.1682-1688>
102. "Chloramphenicol". The American Society of Health-System Pharmacists. Archived from the Original on 25 June 2015. Retrieved 1 August 2015. Accessed 3 November 2022. Available: <https://www.drugs.com/monograph/chloramphenicol.html>
  103. Okoli CI, Chah KF, Ozoh PT, Udedibie AB, Okoli IC. Anti Microbial Resistance Profile of *E. coli* isolates From Tropical Free Range Chickens. *OJHAS*. 2005;4(3).
  104. Busani L, Graziani C, Battisti A, Franco A, Ricci A, Vio D, Digiannatale E et al. Antibiotic resistance in *Salmonella enterica* serotypes Typhimurium, Enteritidis and Infantis from human infections, foodstuffs and farm animals in Italy. *Epidemiol Infect*. 2004;132(2):245-51.
  105. El-Sharkawy H, Tahoun A, El-Gohary AE, El-Abasy M, El-Khayat F, Gillespie T et al. Epidemiological, molecular characterization and antibiotic resistance of *Salmonella enterica* serovars isolated from chicken farms in Egypt. *Gut Pathog*. 2017;9:1–2. <https://doi.org/10.1186/s13099-017-0157-1>
  106. Bailey AM, Weant KA, Baker SN. Prevalence and risk factor analysis of resistant *Escherichia coli* urinary tract infections in the emergency department. *Pharm Practi*. 2013;11(2):96. <https://doi.org/10.4321/s1886-36552013000200006>
  107. Nguyen TK, Nguyen LT, Chau TT, Nguyen TT, Tran BN, Taniguchi T et al. Prevalence and antibiotic resistance of *Salmonella* isolated from poultry and its environment in the Mekong Delta, Vietnam. *Vet World*. 2021;14(12):3216. <https://doi.org/10.14202/vetworld.2021.3216-3223>
  108. Dahshan H, Chuma T, Shahada F, Akiba M, Fujimoto H, Akasaka K et al. Characterization of antibiotic resistance and the emergence of AmpC-producing *Salmonella* Infantis from pigs. *J Vet Med Sci*. 2010;72(11):1437-42. <https://doi.org/10.1292/jvms.10-0186>
  109. Colistin: Uses, Interactions, Mechanism of Action – Drug Bank. Accessed 3 November 2022. Available: <https://go.drugbank.com/drugs/DB00803>
  110. Hess C, Troxler S, Jandreski-Cvetkovic D, Zloch A, Hess M. *Escherichia coli* Isolated from Organic Laying Hens Reveal a High Level of Antimicrobial Resistance despite No Antimicrobial Treatments. *Antibiotics*. 2022;11(4):467. <https://doi.org/10.3390/antibiotics11040467>
  111. Phiri N, Mainda G, Mukuma M, Sinyangwe NN, Banda LJ, Kwenda G et al. Antibiotic-resistant *Salmonella* species and *Escherichia coli* in broiler chickens from farms, abattoirs and open markets in selected districts of Zambia. *J Epidemiol Res*. 2020;6(1):13-21. <https://doi.org/10.5430/jer.v6n1p13>