Chapter

Scenario of Antibiotic Resistance in Developing Countries

Mohammad Mahmudul Hassan

Abstract

Antibiotic resistance is an emerging global concern. It is an increasing threat to public health sectors throughout the world. This devastating problem has drawn attention to researchers and stakeholders after a substantial economic loss for decades resulting from the ineffectiveness of antibiotics to cure infectious diseases in humans and animals. The spectrum of antibiotic resistance varies between developed and developing countries due to having variations in treatment approaches. Antibiotic therapy in the developed countries is usually rational and targeted to specific bacteria, whereas in the developing countries, most of the cases, the use of antibiotics is indiscriminate to the disease etiology. In developing countries, many people are not aware of using antimicrobials. They usually get suggestions from drug sellers and quacks who do not have the authorization to prescribe a drug. If registered doctors and veterinarians are asked to prescribe, then dose, course, and withdrawal period might be maintained adequately. Antibiotic resistance transmission mechanisms between agricultural production systems, environment, and humans in developing countries are very complex. Recent research makes a window to find out the global situation of antibiotic use and resistance pattern. The antibiotic resistance scenario in selected developing countries has been summarized in this chapter based on published literature (**Table 1**). This chapter describes the judicial use of antibiotics and discussed maintaining proper antibiotic dose, course, drug withdrawal period, especially on food-producing animals. The book contains a few recommendations, suggested by the national multi-sectoral surveillance committee to avoid antibiotic resistance organisms in livestock and humans in the developing countries.

Keywords: Antibiotics, Antibiotic resistance pattern, prescribed, registered doctors, developing countries

1. Introduction

After discovering the first antibiotic 'Penicilillin' by Alexander Fleming in 1928, antibiotics played a notable role in saving millions of lives globally. Nowadays, the resistance of antibiotics has intensified significantly throughout the world [1]. Antibiotic resistance is a global problem in both developed and developing countries. The incidence of resistance has increased at an alarming rate in recent years and is expected to increase at a greater rate in the future as antibiotic agents continue to lose their efficiency [2], mostly in many developing or low-and middle-income countries (LMIC). Resistance bacteria do not respect national borders; the development of resistance in the most remote locations can impact the world in a concise time [1]. The widespread use of antibiotics for human and veterinary treatment has led to large-scale dissemination of bacteria with resistance ability to antibiotics in the domestic animal-wildlife-environmental niche via food chain to humans in most developing countries, including Bangladesh [3]. Resistance bacteria are found in the stool and as intestinal flora of healthy individuals that are serving as reservoirs for resistance to multiple antimicrobials [4]. Antibiotics are a mainstay in the treatment of bacterial infections, and thus the worldwide increase in antibiotic-resistance bacteria is of major concern. The problem of antibiotic resistance is not restricted to pathogenic bacteria—it also involves the commensal microbiota, which may become a major reservoir of resistance strains of bacteria [5]. *Escherichia coli* is commonly found in the intestinal tract of humans and animals and can also be concerned with human and animal infectious diseases. Animal food products are important sources of *E. coli* as fecal contamination of processed animal carcasses at the slaughterhouse is frequently occurred. These resistance microorganisms and their possible resistance determinants may be transmitted to humans if these animal origin foods are improperly washed, cooked, or otherwise mishandled [6]. Although most isolates of *E. coli* are nonpathogenic, they are considered an indicator of fecal contamination in food. About 10 to 15% of intestinal coliforms are opportunistic and pathogenic serotypes and cause a variety of lesions in immunocompromised hosts such as animals and humans [7]. Among the diseases that they cause, some are often severe and sometimes lethal such as- meningitis, endocarditis, urinary tract infection, septicemia, and epidemic diarrhea in human, and yolk sac infection, omphalitis, cellulitis, swollen head syndrome, coligranuloma, and colibacillosis in birds [8]. Furthermore, salmonellosis is one of the most frequent foodborne diseases in humans in almost all countries, and *Salmonella enterica ssp. enteritidis*, followed by *typhimurium*, represent the most frequently isolated serotypes [9]. The most common disease syndromes caused by *Salmonella* serotypes in humans are typhoid fever and enteritis [10], and in avian species, *Salmonella* organism causes fowl typhoid and pullorum disease [11]. *Salmonella typhimurium* and *S. dublin* appear to be the commonest serotypes isolated from cattle, although the distribution of these 2 serotypes differs between countries, and the *Salmonella* organism predominantly causes bovine salmonellosis [12]. *S. aureus* causes superficial skin lesions and localized abscesses in a wide range of host animals. *S. aureus* causes deep-seated infections, such as osteomyelitis and endocarditis and more serious skin infections [13]. *S. aureus* is a major cause of hospital-acquired (nosocomial) infection of surgical wounds and, with *S. epidermidis*, causes infections associated with indwelling medical devices [14]. It also causes food poisoning by releasing enterotoxins into animal originated food. *S. aureus* causes toxic shock syndrome by release of superantigens into the blood stream. *S. saprophiticus* causes urinary tract infections in human, frequently in female population [15]. Over the past decade, the changing pattern of resistance against bacteria has depicted the need for new antimicrobial agents [2]. Developing countries are more vulnerable to antimicrobial resistnace issues for their underprivileged health care infrastructure, unregulated agricultural production process, poor sanitation facilities and widespread misuse of antibiotics. In addition, weak monitoring system and improper implimentation of legislative practices on antibiotic sell and uses in the agriculrural production systems, increases the possibilities of registant bacteria in the developing countries. The senario of antibiotic resistance pattern worsen in developing countries as they use antibiotic indiscriminately in clinical treatments and food animal production system as well. With many bacterial causing diseases in human and animal in developing countries, this chapter will be focusing on three most common genera of bacteria viz. Escherichia, *Salmonella* and *Staphylococcus* that are posing threat to public health by gradually getting resistance against many antibiotics. The aim of this chapter is to identify the scenario of antibiotic resistance pattern in developing countries based on published literature (**Table 1**) and compile them to find out the overall spectrum of antibiotic resistance.

DOI: http://dx.doi.org/10.5772/intechopen.94957

Country	Host	Bacteria			Author
		Escherichia coli	***Salmonella* spp.**	***Staphylococcus* spp.**	
Pakistan	Human	Amoxicillin, Ampicillin, Aztreonam, Cephalosporin, Cefotaxime, Ceftriaxone Ciprofloxacin, Floroquinol, Trimethoprim-sulfamethoxazole		Amoxicillin, Ampicillin, Amikacin, Cefoxitin, Chloramphenicol, Ciprofloxacin, Clindamycin, Co-trimoxazole, Doxycycline, Erythromycin, Fusidic acid, Gentamicin, Penicillin, Teicoplanin, Tigecycline, Levofloxacin, Linezolid, Vancomycin	[16–18]
	Poultry and poultry products	Ampicillin, Ciprofloxacin, Colistin, Tetracycline	Pefloxacin	Cefoxitin, Gentamicin, Oxacillin, Penicillin, Levofloxacin, Moxifloxacin	[19–22]
	Livestock			Amikacin, Amoxicillin, Cefoxitin, Ampicillin, Oxacillin, Augmentin, Cefotaxime, Chloramphenicol, Ciprofloxacin, Clindamycin, Enrofloxacin, Erythromycin, Fosfomycin, Gentamycin, Kanamycin, Linezolid, Ofloxacin, Penicillin, Rifampicin, Teicoplanin, Trimethoprim, Vancomycin	[23, 24]
India	Human	Amikacin, Ampicillin, Ampicillin, Augmentin, Cefepime, Cefoxitin, Cefoperazone, Cefotaxime, Quinolones, Ceftazidime, Ceftriaxone, Colistin, Cefuroxime, Cephalosporins, Ciprofloxacin, Co-trimoxazole, Ertapenem, Meropenem, Gentamycin, Imipenem, Nalidixic acid, Nitrofurantoin, Norfloxacin, Piperacillin, Streptomycin, Sulfamethoxazole, Tetracycline	Ampicillin, Azithromycin, Ceftriaxone, Cephalosporins, Chloramphenicol, Fluoroquinolones, Trimethoprim	Ciprofloxacin, Clindamycin, Co-trimoxazole, Erythromycin, Gentamicin	[25–35]
	Poultry and poultry products	Amoxicillin, Ampicillin, Cephalexin, Colistin, Cefoxitin, Chloramphenicol, Neomycin, Ciprofloxacin, Co-trimoxazole, Trimethoprim, Amoxicillin, Erythromycin, Rifamycin, Streptomycin, Doxycycline, Sulfamethoxazole, Nalidixic acid, Tetracycline, Gentamicin	Sulphamethizole, Chloramphenicol Amikacin Ceftazidime, Oxytetracycline, Nalidixic acid	Penicillin, Ciprofloxacin, Tetracycline, Erythromycin Ampicillin, Tetracycline Amoxicillin, Erythromycin Polymyxin-B, Cefoxitin Novobiocin, Oxacillin	[36–47]

Country	Host	Bacteria			Author
		Escherichia coli	*Salmonella* spp.	*Staphylococcus* spp.	
	Livestock	Meropenem, Imipenem, Ertapenem		Methicillin, Penicillin, Ampicillin, Kanamycin, Cefotaxime, Sulphadizine Amoxicillin	[48–51]
	Pet animals			Amoxicillin, Penicillin G, Methicillin, Cloxacillin, Ampicillin, Cephalothin, Cefuroxime, Ceftriaxone, Clavulanate, Neomycin, Streptomycin, Furazolidone, Nitrofurantoin, Ciprofloxacin, Erythromycin, Oleandomycin, Azithromycin, Doripenem, Lincomycin, Clindamycin, Sulfafurazole, Sulfadiazine, Chloramphenicol, Novobiocin, Vancomycin	[50, 52]
	Food and food products	Colistin, Cefotaxime, Ceftazidime, Gentamicin, Tetracycline, Amoxicillin		Oxacillin, Cefoxitin, Penicillin G, Cephalexin, Ampicillin, Methicillin, Kanamycin, Gatifloxacin, Ciprofloxacin	[53–56]
	Environment	Amoxicillin, Ciprofloxacin, Nalidixic acid, Ceftazidime, Cephalosporin, Penicillin, Cefuroxime, Erythromycin, Tetracycline, Ceftazidime, Cefotaxime, Gentamicin, Trimethoprim			[57–60]
Bangladesh	Human	Colistin, Nalidixic Acid, Cefixime, Co-trimoxazole, Ceftazidime, Gentamicin, Amikacin, Imipenam, Ciprofloxacin, Azithromycin, Cefuroxime, Cefotaxime, Ceftriaxone, Meropenem, Nitrofurantoin, Levofloxacin, Meropenem	Ciprofloxacin, Ceftriaxone, Azithromycin, Clindamycin	Nalidixic Acid, Cefixime, Meropenem, Oxacillin, Gentamicin, Ceftazimid, Tocefoxitin, Etracylcin, Cefoxitin, Ciprofloxacin, Chloramphenicol, Clindamycin, Cefotaxime, Levofloxacin	[13, 14, 61–68]
	Poultry	Ampicillin, Tetracycline, Trimethoprim, Nalidixic acid			[7]

Country	Host	Bacteria			Author
		Escherichia coli	***Salmonella* spp.**	***Staphylococcus* spp.**	
	Food and food products	Erythromycin, penicillin, Vancomycin, Novobiocin, Tetracycline, Ceftriaxone, Ampicillin, Azithromycin, Bacitracin, Kanamycin, Nalidixic acid, Sulfamethoxazole	Ampicillin, Azithromycin, Erythromycin, Doxycycline, Sulphonamide, Azithromycin, Novobiocin, Oxytetracycline, Cephradine, Amoxicillin, Erythromycin, Tetracycline, Erythromycin, Vancomycin, Rifampicin, Sulfamethoxazole, Bacitracin	Ampicillin, Chloramphenicol, Nitrofurantoin, Oxytetracycline, Oxytetracycline, Amikacin, Erythromycin, Oxacillin, Ciprofloxacin, Amoxicillin, Trimethoprim, Gentamicin, Penicillin, Erythromycin	[69–74]
	Environment	Ceftazidime, Gentamycin, Tetracycline, Imipenem, Ciprofloxacin, Chloramphenicol, Amoxycillin, Erythromycin, Azithromycin, Streptomycin, Norfloxacin, Cefepime, Cefixime	Ceftazidime, Gentamycin, Imipenem, Ciprofloxacin, Chloramphenicol, Cefoxitin, Tetracycline, Rifampicin, Ampicillin	Ceftazidime, Gentamycin, Azithromycin, Tetracycline, Imipenem, Ciprofloxacin, Chloramphenicol, Methicillin, Vancomycin	[75–77]
Thailand	Human	Trimethoprim/sulfamethoxazole, Colistin, Amoxicillin, Gentamicin, Cefazolin, Cefotaxime, Ceftazidime, Ceftriaxone, Cefixime, Cefalexin, Nalidixic acid, Ciprofloxacin, Norfloxacin, Ofloxacin, Doxycycline, Nitrofurantoin, Ampicillin, Oxacillin, Amikacin, Aztreonam, Cefotaxime, Meropenem, Piperacillin, Chloramphenicol, Amoxycillin, Cotrimoxazole	Trimethoprim-Sulfamethoxazole, Cefotaxime, Ceftazidime, Ceftriaxone, Ceftazidime, Norfloxacin, Nalidixic acid, Tetracycline, Gentamicin, Ampicillin, Ciprofloxacin, Chloramphenicol, Cotrimoxazole	Fosfomycin, Methicillin, Cefoxitin, Penicillin, Oxacillin, Mupirocin, Rifampicin, Cotrimoxazole, Ciprofloxacin, Chloramphenicol, Cefazolin, Clindamycin, Cephalexin, Trimethoprim, Amikacin, Ampicillin, Amoxicillin, Tetracycline, Cloxacillin, Cefotaxime, Meropenem, Piperacillin, Gentamicin, Ofloxacin, Erythromycin	[78–87]
	Livestock			Methicillin, Penicillin, Rifampin, Novobiocin, Tetracycline, Clindamycin, Oxacillin, Linezolid, Erythromycin, Cefoxitin, Kanamycin, Gentamicin, Trimethoprim, Ciprofloxacin, Levofloxacin	[88]
	Food and food products	Ampicillin, Cefotaxime, Cefpodoxime, Aztreonam, Ceftazidime, Imipenem, Gentamicin, Amoxicillin, Ceftriaxone, Nalidixic acid, Amoxicillin, Ampicillin, Cefepime, Amikacin, Doxycycline, Tetracycline, Ciprofloxacin, Co-trimoxazole, Colistin sulfate, Cefoxitin, Enrofloxacin,			[89, 90]

Country	Host	Bacteria			Author
		Escherichia coli	*Salmonella* spp.	*Staphylococcus* spp.	
		Erythromycin, Chloramphenicol, Ceftazidime, Trimethoprim			
	Environment	Penicillin G, Vancomycin, Erythromycin, Ampicillin, Tetracycline, Chloramphenicol, Streptomycin, Neomycin, Kanamycin, Cefazoline, Cefotaxime, Ceftazidime, Gentamicin, Nalidixic acid	Tetracycline, Ampicillin, Streptomycin, Tetracycline, Trimethoprim, Gentamicin, Ciprofloxacin, Nalidixic acid, Penicillin G, Neomycin, Vancomycin, Erythromycin, Kanamycin, Chloramphenicol	Methicillin	[91–94]
Nepal	Human	Amikacin, Ampicillin, Cefotaxime, Levofloxacin, Ciprofloxacin, Gentamicin, Ampicillin, Cefoxitin, Trimethoprim, Nitrofurantoin, Amoxyclav, Piperacillin, Ofloxacin, Cefotaxime, Colistin, Meropenem, Nitrofurantoin, Norfloxacin, Imipenem, Fosfomycin, Cefixime, Piperacillin, Cefoperazone, Nitrofurantoin, Meropenem, Co-trimoxazole, Ceftriaxone, Levofloxacin, Ceftazidime, Chloramphenicol, Nalidixic acid, Piperacillin, Tetracycline	Ciprofloxacin, Ampicillin, Chloramphenicol, Co-trimoxazole, Streptomycin, Nalidixic acid, Trimethoprim-Sulfamethoxazole, Ceftriaxone	Ampicillin, Ceftriaxone, Cefotaxime, Cefixime, Nalidixic acid, Piperacillin, Penicillin, Erythromycin, Clindamycin, Cefoxitin, Chloramphenicol, Ampicillin, Ciprofloxacin, Cotrimoxazole, Cefoxitin, Gentamicin, Tetracycline, Teicoplanin, Cephalexin, Cloxacillin, Erythromycin, Linezolid, Vancomycin, Ampicillin, Azithromycin	[15, 95–107]
	Poultry	Ampicillin, Amikacin			[108]
	Food and food products	Amoxicillin, Tetracycline, Cefotaxime, Nalidixic acid, Cotrimoxazole, Gentamycin	Tetracycline, Chloramphenicol, Nalidixic acid, Amoxicillin	Amoxicillin, Nalidixic acid, Cefotaxime, Tetracycline, Azithromycin, Cotrimoxazole	[109, 110]
Nigeria	Human	Cefuroxime, Cefotaxime, Amoxicillin, Imipenem, Ceftriaxone, Cefalexin, Ampicillin, Ciprofloxacin, Nalidixic Acid, Gentamycin, Nitrofurantoin, Kanamycin, Chloramphenicol, Pefloxacin, Ofloxacin, Streptomycin, Ceftazidime, Tetracycline, Amoxicillin, Trimethoprim, Co-trimoxazole	Ampicillin, Cefotaxime, Chloramphenicol, Trimethoprim-sulfamethoxazole, Ofloxacin, Ciprofloxacin, Co-trimoxazole, Tetracycline, Eftazidime, Ceftriaxone	Streptomycin, Gentamycin, Tetracycline, Cotrimoxazole, Erythromycin, Cloxacillin, Chloramphenicol, Augmentin, Imipenem, Ceftriaxone, Cefoxitin, Ciprofloxacin, Erythromycin, Cefalexin Co-trimoxazole, Nalidixic Acid, Ampicillin, Vancomycin, Azithromycin, Cefuroxime, Amoxicillin, Ceftazidime	[111–120]

Country	Host	Bacteria			Author
		Escherichia coli	*Salmonella* spp.	*Staphylococcus* spp.	
	Poultry	Tetracycline, Ampicillin Nitrofurantoin, Chloramphenicol, Penicillin, Ampicillin, Amoxicillin, Cloxacillin, Augmentin, Tetracycline, Streptomycin, Gentamicin, Erythromycin, Cotrimoxazole, Nalidixic Acid		Penicillin, Ampicillin, Amoxicillin, Cloxacillin, Augmentin, Tetracycline, Streptomycin, Gentamicin Chloramphenicol, Ofloxacin, Erythromycin, Cefuroxime, Cefoxitin, Amoxicillin, Ceftriaxone	[121–123]
	Livestock	Cloxacillin, Penicillin, Teicoplanin, Sulphadimidine, Ampicillin, Tetracycline, Nalidixic acid, Trimethoprim	Amoxicillin, Enrofloxacin	Ampicillin	[124, 125]
	Environment	Ceftazidime, Cephalexin, Ceftriaxone, Cefotaxime, Cephalexin, Tetracycline, Lipocaine, Augmentin, Ceftazidime, Cefuroxime, Ampicillin, Chloramphenicol, Amoxicillin-clavulanic acid, Ciprofloxacin, Ampicillin, Augmentin, Gentamicin	Gentamycin, Ofloxacillin, Amoxycillin, Ciprofloxacin, Tetracycline, Pefloxacin, Lipocaine, Ceftazidime, Ceftriaxone, Cefotaxime, Cefotaxine, Cephalexin, Augmentin, Cefuroxime, Ampicillin, Colistin, Ofloxacin, Cotrimoxazole, Ciprofloxacin, Nitrofurantoin Trimethoprim, Ceftazidime	Ceftazidime, Cephalexin, Ceftriaxone, Cephalexin, Tetracycline, Lipocaine, Amoxicillin	[126–132]
Brazil	Poultry		Amoxicillin, Ceftiofur, Ciprofloxacin, Gentamicin, Chloramphenicol, Tetracycline, Sulfafurazole, Enrofloxacin, Sulfonamide, Spectinomycin, Trimethoprim		[133, 134]
	Human		Ampicillin, Ampicillin, Ceftriaxone, Ceftiofur, Chloramphenicol, Ciprofloxacin, Enrofloxacin Tetracycline, Trimethoprim		[135]
	Food and food products		Sulfonamides, Streptomycin, Tetracycline, Gentamicin, Ceftriaxone, Trimethoprim		[136, 137]

Table 1.
Summary of antibiotic resistance scenario of three bacteria in different samples from selected developing countries.

2. Main text

2.1 Practical scenario of antibiotic resistance pattern in developing countries

An organized literature search approach was used to detect all published studies reporting resistance bacteria in human samples and foods of animal origin in some selected developing countries. PubMed, Science Direct, and Google Scholar were searched for relevant studies published until 2019. The search terms have been adopted into outcome, population, descriptive, and area categories. Based on the study objectives, specific Boolean words were developed using "AND" and "OR". Some modification has been conducted based on the search engine requirements, and advanced search criteria have been used to search Google scholar. The papers were downloaded using the Chattogram Veterinary and Animal Sciences University (CVASU) library network. The Boolean words of each category were combined using "AND", whereas "OR" was used to join the term within a category. Data was extracted and recorded for study location, citation, first author, title, time of study, year of publication, type of specimen, sample size, number of positive specimens, amount of antibiotics, specific antibiotic sensitivity or resistance level percentages, methods of detection used, culturing techniques and resistance genes. Resistance of *E. coli* was mostly seen in humans and poultry compared to *Salmonella* and *Staphylococcus*, and the most resistance drug was Ampicillin and Ciprofloxacin in Pakistan. Furthermore, resistance of salmonella was seen in human samples with Ampicillin, Trimethoprim, and Ceftriaxone. Pefloxacin was resistance to *Salmonella* in derived from poultry. Resistance staphylococcus were observed in cattle, buffalo, poultry, and table egg to antibiotics Penicillin, Ampicillin, Oxacillin, Ciprofloxacin, Trimethoprim, Gentamicin, Linezolid, Erythromycin, Clindamycin, Amikacin, Vancomycin, Chloramphenicol and Cefoxitin. In India, resistance of *E. coli* was mostly seen in poultry, and the human was in second position and the drugs: Ciprofloxacin, Ampicillin, Amoxicillin, Trimethoprim, Gentamicin, Co-trimoxazole and Sulfamethoxazole were found resistance. The highest resistance of Salmonella was detected in poultry with a higher level of Oxytetracycline. In the case of *Staphylococcus* spp., excessive resistance was seen in poultry and cattle with commonly used antimicrobials: Oxacillin, Penicillin G, Ampicillin, Methicillin, Amoxicillin, Erythromycin, Methicillin, Cloxacillin, and Kanamycin. In Bangladesh, the highest antibiotic resistance of *E. coli* was seen in human, and the most resistance drugs are Tetracycline, Ampicillin, Nalidixic acid, Trimethoprim-Sulfamethoxazole, Ciprofloxacin, and Ceftriaxone. Moreover, *Salmonella* resistance to Azithromycin, Ampicillin, and Erythromycin was detected in humans. Resistance of *Staphylococcus* was observed in humans, and the most resistance antibiotics are Ciprofloxacin, Gentamicin, Chloramphenicol, Tetracycline, and doxycycline. In Thailand, the highest resistance of *E. coli* was noticed in human and pig, and the most resistance antibiotics are Ampicillin, Ceftazidime, Tetracycline, Gentamicin, Ciprofloxacin, Norfloxacin, Clavulanic acid, Doxycycline and Colistin sulfate. Research revealed that resistance *Salmonella* was detected in the Thai human population alongside highly resistance antibiotics: Ampicillin, Tetracycline, Ciprofloxacin, Chloramphenicol, and Trimethoprim. On the other hand, resistance *Staphylococcus* was found in humans with higher drug resistance, and the antibiotics were Doxycycline, Gentamicin, Cefoxitin, Ceftriaxone, Methicillin, Tetracycline, Erythromycin, Penicillin, and Cefoxitin. In Nepal, higher resistance of *E. coli* was identified in humans, and many bacteria became resistance, including Doxycycline, Gentamicin, Cefoxitin, Ceftriaxone, Methicillin, Tetracycline, Erythromycin, Penicillin, and Cefoxitin. Besides, resistance salmonella was recognized in humans and foods with resistance antibiotics such as Ampicillin, Ciprofloxacin, Chloramphenicol, Co-trimoxazole, Nalidixic acid, and Amoxicillin. However, antibiotics such as Amikacin, Gentamicin, Ciprofloxacin, Amoxicillin, Tetracycline, Erythromycin, Cefotaxime, Oxacillin, Cefoxitin and Co-trimoxazole recorded resistance against Staphylococcus in Nepal. In Nigeria, the highest resistance of *E. coli* was reported in human and resistance antibiotics were Tetracycline, Ceftazidime, Cefotaxime, Ceftriaxone, Ciprofloxacin, Gentamycin, Sulfamethoxazole, Penicillin, Ampicillin, Amoxicillin, Cloxacillin, Augmentin and Amoxicillin. Moreover, resistance Salmonella was found in the water source in the environment to antibiotics Ampicillin, Cefotaxime, Ceftazidime, Ciprofloxacin, Sulfamethoxazole-trimethoprim, and Tetracycline. Moreover, the resistance *Staphylococcus* was seen in humans and the environment, and the resistance antibiotics were Ceftriaxone, Gentamicin, Erythromycin, Co-trimoxazole, Chloramphenicol, Tetracycline, Streptomycin, Cephalexin, and Ampicillin. Finally, in Brazil, antimicrobial-resistance (AMR) *E. coli* were recorded in water source, and the resistance antibiotics were Ampicillin, Cephalexin, Amoxicillin, and Polymyxin. On the other hand, resistance salmonella was detected in poultry with resistance antibiotics such as Gentamicin, Sulfonamide, Trimethoprim, Ampicillin, and Chloramphenicol, Ciprofloxacin, Enrofloxacin, Tetracycline, and Ceftriaxone. A great majority of antimicrobial classes that are already resistance to the bacteria are used in humans and animals, including domestic animals, poultry and other birds, and commercial farm fishes. These findings of AMR in the agricultural production system, environment, and humans from developing countries pose a threat to the global context.

2.2 Tale of AMR in developing countries

Antibiotics are considered to safeguard against infectious diseases caused by pathogenic bacteria, but unfortunately, antimicrobial resistance becomes a burden in humans, animals, and the environmental niche worldwide. It happened due to the indiscriminate, inappropriate, and unregulated use of antibiotics in animal and agricultural production systems and humans. In developing countries, AMR is overburdened by antibiotics as growth promoters by the farmers, feed dealers, drug sellers, and the lack of approved legislation by the respective government authorities [138]. However, some countries have written and approved legislation, but appropriate implementation and systematic monitoring are not noticed. Multi-drug resistance (MDR) bacteria are increasing day by day at every corner of developing countries and escalate treatment costs. In a recent WHO report, it is speculated that about 10 million people will die, and 100 trillion USD from the world economy will be lost for AMR by 2050 if no effective measures are taken [139]. Humans are mostly suffering in developing countries due to the ineffectiveness of antibiotics to microbes. *E. coli*, *Salmonella* spp. and *Staphylococcus* spp. are now resistance to the commonly used antibiotics and some higher generation antibiotics such as 3rd generation cephalosporins. This might be due to cross-contamination with hospital equipment, animal originated food, and mixing of medical and veterinary hospital effluents in the environments [16, 26, 31, 67, 78, 97].

In highly populated developing countries where there is a shortage of physicians, the people seek to take drugs, including antibiotics, by their own decision or prescription from drug sellers or quacks. Even in the rural area, it is hard to find a licensed doctor or veterinarian to treat people and animals and keep faith in a quack or village doctor. Those quacks, health assistant village doctors, and drug sellers prescribe different antibiotics even for common symptoms such as colds, coughs, and diarrhea, where a simple, supportive treatment course would be enough. Self-medication, both in the human and veterinary sectors, is another major problem for generating antimicrobial resistance. In some cases, licensed doctors and veterinarians are biased to treat antimicrobials due to various pharmaceutical companies [138]. Those unnecessary prescriptions and a broad spectrum of antibiotics in animals and humans have already brought a great disaster in most developing countries [29]. Poor sanitation and hygiene are essential factors for transmitting resistance organisms from animals (mainly food and pet animals) and environment to humans. Countries like Bangladesh, Brazil, India, and Nigeria are mostly suffering from sanitation and hygiene management issues for growing AMR [140]. There is a chance of nosocomial infection in hospital settings, as many hospitals have no facilities for waste disposal and wastewater treatment [14]. There is also a high risk of spreading resistance microbes from patients to their surroundings, especially to caregivers or family members.

Poultry meat is one of the topmost widely accepted food worldwide as a cheap protein source, and more than 90 billion tons of chicken meat produce each year. A large variety of antimicrobials are used in poultry production systems for disease prophylaxis and used as growth promoters to increase growth and productivity [8], which accelerate the expansion of resistance in pathogens and different commensals. Therefore, human health is a great concern with the emergence of resistance pathogens from poultry and AMR residue from poultry meat and eggs [18, 74]. Food producing animals or livestock has, also affected by AMR due to not maintaining proper dose, treatment interval and duration in therapeutics, metaphylactic and prophylactic treatment, and withdrawal periods of different antimicrobials. Growth promoter is another influential factor-like poultry production system in most developing countries [88, 124, 135]. Human-livestock interaction is another vital factor for transmitting resistance microorganisms from food and pet animals to humans or vice versa.

An agreement should be maintained among the scientific community to stop the excessive use of antimicrobials in food animal production system. Thus, it will help to limit the AMR on human health. Otherwise, AMR in food animal pathogens will unavoidably effect on treatment failure of livestock and poultry diseases. As a result, pathogen transmission on the environment will increase, and production loss will be soared, and the economy of developing countries will be hindered. In developing countries, the environment is also contaminated with high levels of resistance organisms and AM residues derived from human, livestock, and poultry waste [124]. Hospital, both human and veterinary wastewater, is the potential source of AMR.

Water is the mainstream potential reservoir of antimicrobial resistance as wastewater contaminated rivers, ponds, and other water bodies. Medical and veterinary hospital effluents (with different types of resistance organisms) were directly drained to the nearby water bodies and contaminated the fishes ultimately consumed by humans. Poor sanitation and hygiene management bring pathogens close to each other's species and accelerate the horizontal resistance gene transmission [140]. Ceftazidime, Cefpodoxime-resistance bacteria were isolated in Nigeria. Moreover, Azithromycin, Tetracycline, Gentamicin, Ciprofloxacin, Cefotaxime, Chloramphenicol, Cefoxitin, and Oxacillin resistance *Staphylococcus aureus* found in both human and veterinary hospital drainage water in Bangladesh [14, 121]. Research in Thailand detected Cefazoline, Cefotaxime, Ceftazidime, Gentamicin, Tetracycline, Chloramphenicol, Kanamycin, and Nalidixic acid resistance *E. coli*, which indicate the vulnerability of AMR in the environment [94]. In food animals in developing countries, antibiotics are frequently used in food and water to the entire group for a prolonged time and often at sub-therapeutic doses. These conditions favor the selection and spread of resistance bacteria within and between animals as well as to humans through food consumption and other environmental pathways.

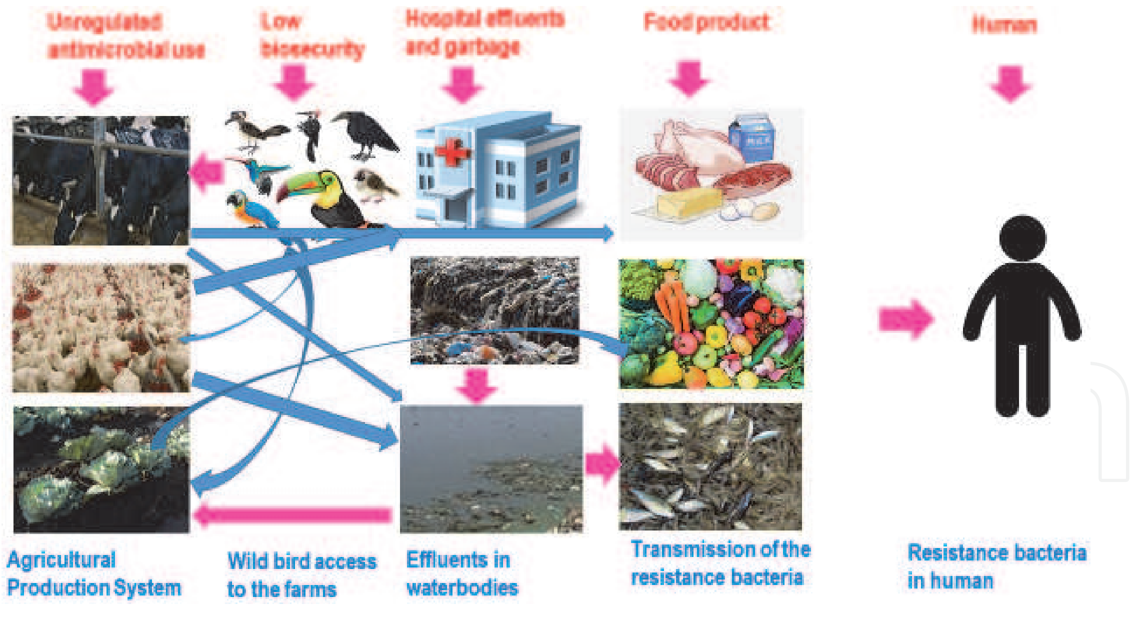

Figure 1.
Complex transmission dynamics of AMR between agricultural production system, environment, and human (credit: MM Hassan; created by using online materials).

To reduce the AMR in developing countries, proper rules and regulations for antibiotic use in humans and animals should be followed. Only registered physicians will prescribe antibiotics for humans; livestock and poultry farming will be conducted with veterinary supervision. Buying and selling antimicrobials should be restricted without prescription. National surveillance with a multi-sectoral committee in the "One Health" concept would be a useful measure for monitoring antibiotic use in animals and humans.

2.3 Transmissions dynamics of AMR in developing countries

Due to the unregulated use of antibiotics in agricultural production systems in developing countries, bacteria become resistance to single or multiple antimicrobials. These resistance bacteria or genes are transmitted directly from agricultural food products such as meat, milk, egg, fish, and vegetables to humans. Hospital effluents, garbage, livestock effluents contaminated with resistance bacteria drained to the nearby water body where fishes raised, and this water is also used in the crop fields for their productions. It is another way to transmit resistance bacteria from crops and fish to humans. The fate of AMR bacteria in the agricultural production system and environment is still unclear. Could AMR bacteria and mobile genetic elements carrying the resistance genes further evolve after their transfer to the environment? There are knowledge gaps regarding the magnitude and dynamic nature of spread regarding antimicrobial resistance bacteria and antimicrobial resistance genes within and between different ecological niches on farms, which deserve to be considered when assessing antimicrobial resistance bacteria's transmission the food chain. Moreover, the transmission pathway of resistance bacteria between the agricultural production systems, environment, and humans in developing countries is very complex and given in **Figure 1**.

3. Conclusions

Antimicrobial resistance has shown a profound surge in developing countries as well as around the globe. In developing countries, antibiotic resistance on different microorganisms, especially *E. coli*, *Salmonella* spp. and *Staphylococcus* spp. are skyrocketing in different agricultural production systems, environments, and humans due to the poor management and practices, which is truly terrifying. Further studies are required based on the international standard to evaluate AMR nationwide in every developing country. It is essential to sketch a proper multi-sectoral surveillance plan to research, diagnose and execute necessary steps for combating against multi drugs resistance hitch. There is a need for detailed system biology analysis of resistance development *in-situ*. Metagenomic analysis of bacterial pathogens from diverse sources, including hospitals, veterinary clinics, agricultural production systems including live animal production, marketing, processing, and waste water plants, might underline bacterial pathogens' evolution for integrin-mediated resistance gene transfer in resistance evolution. One Health approach by each government among all stakeholders could promote better exercise and antimicrobial stewardship.

Acknowledgements

I acknowledge the Department of Physiology, Biochemistry and Pharmacology, Faculty of Veterinary Medicine, Chattogram Veterinary and Animal Sciences University, Bangladesh, to contribute my research. I also acknowledge Shahneaz, Mazhar, Shaikat, Mahabub, Tanzin, Nayem, and Kaisar for their help in writing and checking the document. Finally, I acknowledge the Bangladesh Bureau of Educational Information and Statistics (BANBEIS) project number: SD 2019967 for funding.

Conflict of interest

Not exist.

Author details

Mohammad Mahmudul Hassan
Department of Physiology, Biochemistry and Pharmacology, Faculty of Veterinary Medicine, Chattogram Veterinary and Animal Sciences University, Khulshi, Chattogram, Bangladesh

*Address all correspondence to: miladhasan@yahoo.com

References

[1] Shibl A, Memish Z, Osoba A. Antibiotic resistance in developing countries. Journal of chemotherapy. 2001;13(sup1): 40–4.

[2] Appelbaum PC. Microbiology of antibiotic resistance in *Staphylococcus aureus*. Clinical Infectious Diseases. 2007;45(Supplement_3):S165-S70.

[3] Khan SA, Imtiaz MA, Sayeed MA, Shaikat AH, Hassan MM. Antimicrobial resistance pattern in domestic animal-wildlife-environmental niche via the food chain to humans with a Bangladesh perspective; a systematic review. BMC Veterinary Research. 2020;16(1):1–13.

[4] Reinthaler F, Posch J, Feierl G, Wüst G, Haas D, Ruckenbauer G, et al. Antibiotic resistance of *E. coli* in sewage and sludge. Water research. 2003;37(8): 1685–90.

[5] Erb A, Stürmer T, Marre R, Brenner H. Prevalence of antibiotic resistance in Escherichia coli: overview of geographical, temporal, and methodological variations. European Journal of Clinical Microbiology & Infectious Diseases. 2007;26(2):83–90.

[6] Sáenz Y, Zarazaga M, Briñas L, Lantero M, Ruiz-Larrea F, Torres C. Antibiotic resistance in Escherichia coli isolates obtained from animals, foods and humans in Spain. International journal of antimicrobial agents. 2001;18 (4):353–8.

[7] 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. Journal of advanced veterinary and animal research. 2019;6(3):272.

[8] Akond MA, Alam S, Hassan S, Shirin M. Antibiotic resistance of Escherichia coli isolated from poultry and poultry environment of Bangladesh. Internet Journal of Food Safety. 2009;11: 19–23.

[9] Bouchrif B, Paglietti B, Murgia M, Piana A, Cohen N, Ennaji MM, et al. Prevalence and antibiotic-resistance of Salmonella isolated from food in Morocco. The Journal of Infection in Developing Countries. 2009;3(01): 035–40.

[10] Santos RL, Zhang S, Tsolis RM, Kingsley RA, Adams LG, Bäumler AJ. Animal models of Salmonella infections: enteritis versus typhoid fever. Microbes and infection. 2001;3(14–15):1335–44.

[11] Zhang-Barber L, Turner A, Barrow P. Vaccination for control of Salmonella in poultry. Vaccine. 1999;17 (20–21):2538–45.

[12] Wray C, Sojka W. Bovine salmonellosis. Journal of Dairy Research. 1977;44(2):383–425.

[13] Parvez MAK, Ferdous RN, Rahman MS, Islam S. Healthcare-associated (HA) and community-associated (CA) methicillin resistant *Staphylococcus aureus* (MRSA) in Bangladesh–Source, diagnosis and treatment. Journal of Genetic Engineering and Biotechnology. 2018;16 (2):473–8.

[14] Islam T, Kubra K, Chowdhury MMH. Prevalence of methicillin-resistant *Staphylococcus aureus* in hospitals in Chittagong, Bangladesh: A threat of nosocomial infection. Journal of microscopy and ultrastructure. 2018;6(4):188.

[15] Shrestha LB, Baral R, Poudel P, Khanal B. Clinical, etiological and antimicrobial susceptibility profile of pediatric urinary tract infections in a tertiary care hospital of Nepal. BMC pediatrics. 2019;19(1):36.

[16] Fatima S, Muhammad IN, Khan MN, Jamil S. Phenotypic expression and prevalence of multi drug resistant extended spectrum beta-lactamase producing Escherichia coli and *Klebsiella pneumoniae* in Karachi, Pakistan. Pak J Pharm Sci. 2018;31(4): 1379–84.

[17] Rasool MS, Siddiqui F, Ajaz M, Rasool SA. Prevalence and antibiotic resistance profiles of Gram negative bacilli associated with urinary tract infections (UTIs) in Karachi, Pakistan. Pakistan Journal of Pharmaceutical Sciences. 2019;32(6).

[18] Jamil B, Gawlik D, Syed MA, Shah AA, Abbasi SA, Müller E, et al. Hospital-acquired methicillin-resistant *Staphylococcus aureus* (MRSA) from Pakistan: molecular characterisation by microarray technology. European Journal of Clinical Microbiology & Infectious Diseases. 2018;37(4): 691–700.

[19] 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. Microbial Drug Resistance. 2019;25(1):133–42.

[20] Azam M, Mohsin M, Saleemi MK. Virulence-associated genes and antimicrobial resistance among avian pathogenic Escherichia coli from colibacillosis affected broilers in Pakistan. Tropical animal health and production. 2019;51(5):1259–65.

[21] Lv J, Mohsin M, Lei S, Srinivas S, Wiqar RT, Lin J, et al. Discovery of a mcr-1-bearing plasmid in commensal colistin-resistant Escherichia coli from healthy broilers in Faisalabad, Pakistan. Virulence. 2018;9(1):994–9.

[22] Syed MA, Shah SHH, Sherafzal Y, Shafi-ur-Rehman S, Khan MA, Barrett JB, et al. Detection and molecular characterization of methicillin-resistant *Staphylococcus aureus* from table eggs in Haripur, Pakistan. Foodborne pathogens and disease. 2018;15(2):86–93.

[23] Maalik A, Shahzad A, Iftikhar A, Rizwan M, Ahmad H, Khan I. Prevalence and Antibiotic Resistance of *Staphylococcus aureus* and Risk Factors for Bovine Subclinical Mastitis in District Kasur, Punjab, Pakistan. Pakistan Journal of Zoology. 2019;51(3): 1123.

[24] Aqib AI, Nighat S, Rais A, Sana S, Jamal MA, Kulyar MF-e-A, et al. Drug susceptibility profile of *Staphylococcus aureus* isolated from mastitic milk of goats and risk factors associated with goat mastitis in Pakistan. Pakistan Journal of Zoology. 2019;51(1).

[25] Singh AK, Das S, Singh S, Gajamer VR, Pradhan N, Lepcha YD, et al. Prevalence of antibiotic resistance in commensal Escherichia coli among the children in rural hill communities of Northeast India. PloS one. 2018;13(6).

[26] Vigi C, Gaurav S, Naveen C, Raghuvanshi R. High prevalence of multiple drug resistance among pediatric Escherichia Coli infections. International Journal of Medical Research & Health Sciences. 2018;5(10): 166–9.

[27] Mahalingam N, Manivannan B, Khamari B, Siddaramappa S, Adak S, Bulagonda EP. Detection of antibiotic resistance determinants and their transmissibility among clinically isolated carbapenem-resistant Escherichia coli from South India. Medical Principles and Practice. 2018;27 (5):428–35.

[28] Mohsin J, Pál T, Petersen JE, Darwish D, Ghazawi A, Ashraf T, et al. Plasmid-mediated colistin resistance gene mcr-1 in an Escherichia coli ST10

bloodstream isolate in the Sultanate of Oman. Microbial Drug Resistance. 2018; 24(3):278–82.

[29] Purohit MR, Lindahl LF, Diwan V, Marrone G, Lundborg CS. High levels of drug resistance in commensal *E. coli* in a cohort of children from rural central India. Scientific reports. 2019;9(1):1–11.

[30] Shanthi B, Selvi R, Madhumathy A. Antimicrobial susceptibility pattern of Escherichia coli from patients with urinary tract infections in a tertiary care hospital. Int J Curr Microbiol App Sci. 2018;7(01):289–94.

[31] Veeraraghavan B, Walia K. Antimicrobial susceptibility profile & resistance mechanisms of Global Antimicrobial Resistance Surveillance System (GLASS) priority pathogens from India. The Indian Journal of Medical Research. 2019;149(2):87.

[32] Klemm EJ, Shakoor S, Page AJ, Qamar FN, Judge K, Saeed DK, et al. Emergence of an extensively drug-resistant *Salmonella enterica* serovar Typhi clone harboring a promiscuous plasmid encoding resistance to fluoroquinolones and third-generation cephalosporins. MBio. 2018;9(1): e00105–18.

[33] Chatham-Stephens K, Medalla F, Hughes M, Appiah GD, Aubert RD, Caidi H, et al. Emergence of extensively drug-resistant Salmonella Typhi infections among travelers to or from Pakistan—United States, 2016–2018. Morbidity and Mortality Weekly Report. 2019;68(1):11.

[34] Tahir MF, Afzal F, Athar M. Prevalence and Antimicrobial Susceptibility Patterns of Salmonella Enteritidis and Salmonella Typhimurium Isolates from Commercial Poultry in Punjab, Pakistan. Iproceedings. 2018;4(1):e10639.

[35] Engsbro AL, Jespersen HSR, Goldschmidt MI, Mollerup S, Worning P, Pedersen MS, et al. Ceftriaxone-resistant *Salmonella enterica* serotype Typhi in a pregnant traveller returning from Karachi, Pakistan to Denmark, 2019. Eurosurveillance. 2019; 24(21).

[36] Bhave S, Kolhe R, Mahadevaswamy R, Bhong C, Jadhav S, Nalband S, et al. Phylogrouping and antimicrobial resistance analysis of extraintestinal pathogenic Escherichia coli isolated from poultry species. Turkish Journal of Veterinary and Animal Sciences. 2019;43(1):117–26.

[37] Subedi M, Luitel H, Devkota B, Bhattarai RK, Phuyal S, Panthi P, et al. Antibiotic resistance pattern and virulence genes content in avian pathogenic Escherichia coli (APEC) from broiler chickens in Chitwan, Nepal. BMC veterinary research. 2018; 14(1):113.

[38] Majhi M, Pamia J, Panda SK, Samal L, Mishra R. Effect of Age and Season on Enteritis and Antibiotic Sensitivity Test of *E. coli* Isolated from Infected Chickens in Odisha, India. Int J Curr Microbiol App Sci. 2018;7(3): 2037–45.

[39] Magray S, Wani S, Kashoo Z, Bhat M, Adil S, Farooq S, et al. Serological diversity, molecular characterisation and antimicrobial sensitivity of avian pathogenic Escherichia coli (APEC) isolates from broiler chickens in Kashmir, India. Animal production science. 2019;59(2): 338–46.

[40] Zhang J, Chen L, Wang J, Yassin AK, Butaye P, Kelly P, et al. Molecular detection of colistin resistance genes (mcr-1, mcr-2 and mcr-3) in nasal/oropharyngeal and anal/cloacal swabs from pigs and poultry. Scientific reports. 2018;8(1):1–9.

[41] Jamoh K, Rajkhowa T, Singh Y, Ravindran R, Arya R. Antimicrobial

resistant Escherichia coli and associated colibacillosis in poultry population of Mizoram. Indian Journal of Veterinary Pathology. 2018;42(3):185–90.

[42] Khoirani K, Indrawati A, Setiyaningsih S. Detection of Ampicillin Resistance Encoding Gene of Escherichia coli from Chickens in Bandung and Purwakarta. Jurnal Riset Veteriner Indonesia (Journal of The Indonesian Veterinary Research). 2019;3(1).

[43] Enany M, Hassan W, Ismail N. Prevalence of Antibiotic Resistance Genes among *E. coli* Strains Isolated from Poultry in Suez Canal Area. Suez Canal Veterinary Medicine Journal SCVMJ. 2018;23(1):53–65.

[44] Maru V, Ranade V. Antibiotic resistant-biofilm forming Escherichia coli and Salmonella spp. in poultry raw meat. Indian Journal of Veterinary Research (The). 2018;27(2):33–8.

[45] Waghamare R, Paturkar A, Vaidya V, Zende R, Dubal Z, Dwivedi A, et al., editors. Phenotypic and genotypic drug resistance profile of Salmonella serovars isolated from poultry farm and processing units located in and around Mumbai city, India, Veterinary World, 11 (12): 1682–16882018: Abstract.

[46] Zehra A, Gulzar M, Singh R, Kaur S, Gill J. Prevalence, multidrug resistance and molecular typing of methicillin-resistant *Staphylococcus aureus* (MRSA) in retail meat from Punjab, India. Journal of global antimicrobial resistance. 2019;16:152–8.

[47] Ruban SW, Babu RN, Abraham RJ, Senthilkumar T, Kumaraswamy P, Porteen K, et al. Prevalence and Antimicrobial Susceptibility of *Staphylococcus aureus* Isolated from Retail Chicken Meat in Chennai, India. Journal of Animal Research. 2018;8(3): 423–7.

[48] Murugan MS, Sinha D, Kumar OV, Yadav AK, Pruthvishree B, Vadhana P, et al. Epidemiology of carbapenem-resistant Escherichia coli and first report of blaVIM carbapenemases gene in calves from India. Epidemiology & Infection. 2019;147.

[49] Shah MS, Qureshi S, Kashoo Z, Farooq S, Wani SA, Hussain MI, et al. Methicillin resistance genes and in vitro biofilm formation among *Staphylococcus aureus* isolates from bovine mastitis in India. Comparative immunology, microbiology and infectious diseases. 2019;64:117–24.

[50] Yadav R, Kumar A, Singh VK, Yadav SK. Prevalence and antibiotyping of *Staphylococcus aureus* and methicillin-resistant *S. aureus* (MRSA) in domestic animals in India. Journal of global antimicrobial resistance. 2018;15:222–5.

[51] Ruban SW, Babu RN, Abraham RJ, Senthilkumar T, Kumraswamy P, Rao VA. Prevalence of methicillin resistant *Staphylococcus aureus* in retail buffalo meat in Chennai, India. Buffalo Bulletin. 2018;37(1):51–8.

[52] Dutta TK, Chakraborty S, Das M, Mandakini R. Multidrug-resistant Staphylococcus pettenkoferi isolated from cat in India. Veterinary world. 2018;11(10):1380.

[53] Ghafur A, Shankar C, GnanaSoundari P, Venkatesan M, Mani D, Thirunarayanan M, et al. Detection of chromosomal and plasmid-mediated mechanisms of colistin resistance in Escherichia coli and *Klebsiella pneumoniae* from Indian food samples. Journal of global antimicrobial resistance. 2019;16:48–52.

[54] Batabyal K, Banerjee A, Pal S, Dey S, Joardar SN, Samanta I, et al. Detection, characterization, and antibiogram of extended-spectrum beta-lactamase Escherichia coli isolated from bovine milk samples in West Bengal, India. Veterinary world. 2018;11(10):1423.

[55] Patel R, Kumar R, Savalia C, Patel N. Isolation of *Staphylococcus aureus* from Raw Cattle Milk and their Drug Resistance Pattern. Int J Curr Microbiol App Sci. 2018;7(2):836–40.

[56] Sivakumar M, Dubal ZB, Kumar A, Bhilegaonkar K, Kumar ORV, Kumar S, et al. Virulent methicillin resistant *Staphylococcus aureus* (MRSA) in street vended foods. Journal of food science and technology. 2019;56(3):1116–26.

[57] Sharma P. Water Quality of River Narmada at Gwari Ghat Jabalpur (MP, India) in Terms of Microbial Load, Drug Resistance and Potability. Journal of Applied & Environmental Microbiology. 2018;6(1):25–9.

[58] Dhawde R, Macaden R, Saranath D, Nilgiriwala K, Ghadge A, Birdi T. Antibiotic resistance characterization of environmental *E. coli* isolated from River Mula-Mutha, Pune District, India. International journal of environmental research and public health. 2018; 15(6):1247.

[59] Odonkor ST, Addo KK. Prevalence of multidrug-resistant Escherichia coli isolated from drinking water sources. International journal of microbiology. 2018;2018.

[60] Rayasam SD, Ray I, Smith KR, Riley LW. Extraintestinal pathogenic escherichia coli and antimicrobial drug resistance in a maharashtrian drinking water system. The American journal of tropical medicine and hygiene. 2019;100 (5):1101–4.

[61] Asaduzzaman M, Baral K, Islam MM, Nayem A, Alam J, Juliana FM, et al. Susceptibility pattern of second line antibiotic colistin against gram negative bacteria causing urinary tract infection in selected areas Dhaka city, Bangladesh. Eur J Biomed Pharm Sci. 2018;5(3):874–9.

[62] Asaduzzaman M, Miah AA, Bhuiyan M, Alam J, Juliana F, Hossain N. Resistant pattern of nalidixic acid against uropathogens in selected areas of Dhaka city, Bangladesh. Eur J Biomed Pharm Sci. 2018;5(3):90–5.

[63] Asaduzzaman M, Asaduzzaman Shamim M, Mian S, Alam MJ, Juliana FM, Hossain N, et al. Resistance pattern of cefixime against uropathogens causing urinary tract infection in selected areas of Dhaka city, Bangladesh. Int J Eng Sci. 2018;7 (1):33–9.

[64] Acherjya GK, Tarafder K, Ghose R, Islam DU, Ali M, Akhtar N, et al. Pattern of Antimicrobial Resistance to Escherichia Coli Among the Urinary Tract Infection Patients in Bangladesh. American Journal of Internal Medicine. 2018;6(5):132–7.

[65] Asaduzzaman M, Hasan MZ, Khatun M, Alam J, Hossain N, Das B, et al. Resistance pattern of levofloxacin against uropathogens causing urinary tract infection in selected areas of Dhaka city. Bangladesh J Biol Agri Healthc. 2018;8(4):74–81.

[66] Asaduzzaman M, Ullah MM, Redwan S, Alam J, Juliana FM, Hossain N, et al. Emergence of meropenem resistance in pathogens recovered from urine cultures in Bangladesh. IOSR JPBS. 2018;13(3):41–7.

[67] Tanmoy AM, Westeel E, De Bruyne K, Goris J, Rajoharison A, Sajib MS, et al. *Salmonella enterica* Serovar Typhi in Bangladesh: exploration of genomic diversity and antimicrobial resistance. MBio. 2018;9 (6):e02112–18.

[68] Ahsan S, Rahman S. Azithromycin resistance in clinical isolates of *Salmonella enterica* serovars Typhi and paratyphi in Bangladesh. Microbial Drug Resistance. 2019;25(1):8–13.

[69] Jahan M, Rahman M, Rahman M, Sikder T, Uson-Lopez RA, Selim ASM,

et al. Microbiological safety of street-vended foods in Bangladesh. Journal of Consumer Protection and Food Safety. 2018;13(3):257–69.

[70] Banik A, Abony M, Datta S, Towhid ST. Microbiological quality of ready-to-eat food from Dhaka, Bangladesh. Current Research in Nutrition and Food Science Journal. 2019;7(1):161–8.

[71] Rahman M, Rahman A, Islam M, Alam M. Detection of multi–drug resistant Salmonella from milk and meat in Bangladesh. Bangladesh Journal of Veterinary Medicine. 2018;16(1):115–20.

[72] Hasan M, Kabir SL, Rahman T, Sarker YA. Bacteriological quality assessment of buffalo meat collected from different districts of Bangladesh with particular emphasis on the molecular detection and antimicrobial resistance of the isolated Salmonella species. Asian Australas. J Food Saf Secur. 2018;2:12–20.

[73] Rahman MA, Rahman AA, Islam MA, Alam MM. Multi–drug resistant *Staphylococcus aureus* isolated from milk, chicken meat, beef and egg in Bangladesh. Research in Agriculture Livestock and Fisheries. 2018;5(2):175–83.

[74] Hoque M, Das Z, Rahman A, Haider M, Islam M. Molecular characterization of *Staphylococcus aureus* strains in bovine mastitis milk in Bangladesh. International journal of veterinary science and medicine. 2018;6 (1):53–60.

[75] Debnath T, Bhowmik S, Islam T, Chowdhury MMH. Presence of multidrug-resistant bacteria on mobile phones of healthcare workers accelerates the spread of nosocomial infection and Regarded as a Threat to Public Health in Bangladesh. Journal of microscopy and ultrastructure. 2018; 6(3):165.

[76] Hassan MS, Kabir SL, Sarker YA, Rahman MT. Bacteriological assessment of tap water collected from different markets of Mymensingh, Gazipur and Sherpur districts of Bangladesh with special focus on the molecular detection and antimicrobial resistance of the isolated Escherichia coli. Asian Australas. J Food Saf Secur. 2018;2(1): 21–8.

[77] Anwar T. Determination of prevalence and antibiotic susceptibility pattern of bacteria isolated from household and restaurant kitchen utensils of Dhaka, Bangladesh: BRAC Univeristy; 2018.

[78] Whistler T, Sapchookul P, McCormick DW, Sangwichian O, Jorakate P, Makprasert S, et al. Epidemiology and antimicrobial resistance of invasive non-typhoidal Salmonellosis in rural Thailand from 2006–2014. PLoS neglected tropical diseases. 2018;12(8):e0006718.

[79] Luk-In S, Chatsuwan T, Pulsrikarn C, Bangtrakulnonth A, Rirerm U, Kulwichit W. High prevalence of ceftriaxone resistance among invasive *Salmonella enterica* serotype Choleraesuis isolates in Thailand: the emergence and increase of CTX-M-55 in ciprofloxacin-resistant S. Choleraesuis isolates. International Journal of Medical Microbiology. 2018; 308(4):447–53.

[80] Jaganath D, Jorakate P, Makprasert S, Sangwichian O, Akarachotpong T, Thamthitiwat S, et al. *Staphylococcus aureus* bacteremia incidence and methicillin resistance in rural Thailand, 2006–2014. The American journal of tropical medicine and hygiene. 2018;99(1):155–63.

[81] Kitti T, Seng R, Saiprom N, Thummeepak R, Chantratita N, Boonlao C, et al. Molecular characteristics of methicillin-resistant staphylococci clinical isolates from a

tertiary Hospital in Northern Thailand. Canadian Journal of Infectious Diseases and Medical Microbiology. 2018;2018.

[82] Pootong A, Mungkornkeaw N, Norrapong B, Cowawintaweewat S. Phylogenetic background, drug susceptibility and virulence factors of uropathogenic *E. coli* isolate in a tertiary university hospital in central Thailand. Tropical Biomedicine. 2018;35(1): 195–204.

[83] Eiamphungporn W, Yainoy S, Jumderm C, Tan-arsuwongkul R, Tiengrim S, Thamlikitkul V. Prevalence of the colistin resistance gene mcr-1 in colistin-resistant Escherichia coli and *Klebsiella pneumoniae* isolated from humans in Thailand. Journal of global antimicrobial resistance. 2018;15:32–5.

[84] Prasertsiriphong S, Chootong R, Jamulitrat S, Penghmak M. Prevalence of Antibiotic Resistance in Escherichia coli from the Fecal Flora of Humans in a Rural Area of Songkhla Province. Journal of Health Science and Medical Research. 2019:321–7.

[85] Dahal RH, Chaudhary DK. Microbial infections and antimicrobial resistance in Nepal: current trends and recommendations. The open microbiology journal. 2018;12:230.

[86] Pokhrel B, Koirala T, Shah G, Joshi S, Baral P. Bacteriological profile and antibiotic susceptibility of neonatal sepsis in neonatal intensive care unit of a tertiary hospital in Nepal. BMC pediatrics. 2018;18(1):208.

[87] Yadav NS, Sharma S, Chaudhary DK, Panthi P, Pokhrel P, Shrestha A, et al. Bacteriological profile of neonatal sepsis and antibiotic susceptibility pattern of isolates admitted at Kanti Children's Hospital, Kathmandu, Nepal. BMC research notes. 2018;11(1):301.

[88] Pumipuntu N, Tunyong W, Chantratita N, Diraphat P, Pumirat P, Sookrung N, et al. Staphylococcus spp. associated with subclinical bovine mastitis in central and northeast provinces of Thailand. PeerJ. 2019;7: e6587.

[89] Tansawai U, Sanguansermsri D, Na-udom A, Walsh TR, Niumsup PR. Occurrence of extended spectrum β-lactamase and AmpC genes among multidrug-resistant Escherichia coli and emergence of ST131 from poultry meat in Thailand. Food control. 2018;84: 159–64.

[90] Nuangmek A, Rojanasthien S, Chotinun S, Yamsakul P, Tadee P, Thamlikitkul V, et al. Antimicrobial resistance in ESBL-producing Escherichia coli isolated from layer and pig farms in Thailand. Acta Scientiae Veterinariae. 2018;46(1):8.

[91] Sripaurya B, Ngasaman R, Benjakul S, Vongkamjan K. Virulence genes and antibiotic resistance of Salmonella recovered from a wet market in Thailand. Journal of Food Safety. 2019;39(2):e12601.

[92] Pongsilp N, Nimnoi P. Diversity and antibiotic resistance patterns of enterobacteria isolated from seafood in Thailand. CyTA-Journal of Food. 2018; 16(1):793–800.

[93] Intrakamhaeng M, Singpun Y, Sreward C, Phakhunthod S, Ketphonthong S. The occurrence of MRSA, MSSA and antibiotic resistance, related factors in area of dairy farming of Mahasarakham province, Thailand. International Journal of Agricultural Technology. 2018;14(7 Special Issue): 1259–66.

[94] Fukuda A, Usui M, Okubo T, Tagaki C, Sukpanyatham N, Tamura Y. Co-harboring of cephalosporin (bla)/ colistin (mcr) resistance genes among Enterobacteriaceae from flies in Thailand. FEMS microbiology letters. 2018;365(16):fny178.

[95] Thapa S, Sapkota LB. Changing trend of neonatal septicemia and antibiotic susceptibility pattern of isolates in Nepal. International journal of pediatrics. 2019;2019.

[96] Manandhar S, Singh A, Varma A, Pandey S, Shrivastava N. Biofilm producing clinical *Staphylococcus aureus* isolates augmented prevalence of antibiotic resistant cases in tertiary care hospitals of Nepal. Frontiers in microbiology. 2018;9:2749.

[97] Mahato S, Mahato A, Yadav J. Prevalence and identification of uropathogens in eastern Nepal and understanding their antibiogram due to multidrug resistance and Esbl. Asian Pac J Microbiol Res. 2018;2(1):09–17.

[98] Britto CD, Dyson ZA, Duchene S, Carter MJ, Gurung M, Kelly DF, et al. Laboratory and molecular surveillance of paediatric typhoidal Salmonella in Nepal: Antimicrobial resistance and implications for vaccine policy. PLoS neglected tropical diseases. 2018;12(4): e0006408.

[99] Margulieux KR, Srijan A, Ruekit S, Nobthai P, Poramathikul K, Pandey P, et al. Extended-spectrum β-lactamase prevalence and virulence factor characterization of enterotoxigenic Escherichia coli responsible for acute diarrhea in Nepal from 2001 to 2016. Antimicrobial Resistance & Infection Control. 2018;7(1):87.

[100] Neopane P, Nepal HP, Shrestha R, Uehara O, Abiko Y. In vitro biofilm formation by *Staphylococcus aureus* isolated from wounds of hospital-admitted patients and their association with antimicrobial resistance. International journal of general medicine. 2018;11:25.

[101] Khanal LK, Adhikari RP, Guragain A. Prevalence of Methicillin Resistant *Staphylococcus aureus* and Antibiotic Susceptibility Pattern in a Tertiary Hospital in Nepal. Journal of Nepal Health Research Council. 2018;16 (2):172–4.

[102] Petersiel N, Shresta S, Tamrakar R, Koju R, Madhup S, Shresta A, et al. The epidemiology of typhoid fever in the Dhulikhel area, Nepal: A prospective cohort study. PloS one. 2018;13(9).

[103] Shrestha R, Khanal S, Poudel P, Khadayat K, Ghaju S, Bhandari A, et al. Extended spectrum β-lactamase producing uropathogenic Escherichia coli and the correlation of biofilm with antibiotics resistance in Nepal. Annals of Clinical Microbiology and Antimicrobials. 2019;18(1):42.

[104] Wagle S, Khanal BR, Tiwari BR. High susceptibility of fosfomycin to uropathogenic Escherichia coli isolated at Tertiary Care Hospital of Nepal. Journal of Advances in Microbiology. 2018:1–8.

[105] Roberts MC, Joshi PR, Greninger AL, Melendez D, Paudel S, Acharya M, et al. The human clone ST22 SCC mec IV methicillin-resistant *Staphylococcus aureus* isolated from swine herds and wild primates in Nepal: is man the common source? FEMS microbiology ecology. 2018;94(5): fiy052.

[106] Maharjan A, Bhetwal A, Shakya S, Satyal D, Shah S, Joshi G, et al. Ugly bugs in healthy guts! Carriage of multidrug-resistant and ESBL-producing commensal Enterobacteriaceae in the intestine of healthy Nepalese adults. Infection and drug resistance. 2018;11:547.

[107] Gurung RR, Maharjan P, Chhetri GG. Antibiotic resistance pattern of *Staphylococcus aureus* with reference to MRSA isolates from pediatric patients. Future Science OA. 2020(0):FSO464.

[108] Subedi M, Bhattarai RK, Devkota B, Phuyal S, Luitel H.

Correction to: Antibiotic resistance pattern and virulence genes content in avian pathogenic Escherichia coli (APEC) from broiler chickens in Chitwan, Nepal. BMC veterinary research. 2018;14(1):166.

[109] Bantawa K, Sah SN, Limbu DS, Subba P, Ghimire A. Antibiotic resistance patterns of *Staphylococcus aureus*, Escherichia coli, Salmonella, Shigella and Vibrio isolated from chicken, pork, buffalo and goat meat in eastern Nepal. BMC research notes. 2019;12(1):1–6.

[110] Saud B, Paudel G, Khichaju S, Bajracharya D, Dhungana G, Awasthi MS, et al. Multidrug-resistant bacteria from raw meat of buffalo and chicken, Nepal. Veterinary medicine international. 2019;2019.

[111] Dabo NT, Muhammad B, Saka HK, Kalgo ZM, Raheem RA. Antibiotic Resistance Pattern of Escherichia coli Isolated from Diarrhoeic and Non-diarrhoeic Under Five Children in Kano, Nigeria. Journal of Microbiology and Biotechnology. 2019;4(3):94–102.

[112] Osungunna MO, Onawunmi GO. Antibiotic resistance profiles of biofilm-forming bacteria associated with urine and urinary catheters in a tertiary hospital in Ile-Ife, Nigeria. Southern African Journal of Infectious Diseases. 2018;33(3):80–5.

[113] Omoyibo EE, Oladele AO, Ibrahim MH, Adekunle OT. Antibiotic susceptibility of wound swab isolates in a tertiary hospital in Southwest Nigeria. Annals of African medicine. 2018; 17(3):110.

[114] Oli AN, Ogbuagu VI, Ejikeugwu CP, Iroha IR, Ugwu MC, Ofomata CM, et al. Multi-Antibiotic Resistance and Factors Affecting Carriage of Extended Spectrum β-Lactamase-Producing Enterobacteriaceae in Pediatric Population of Enugu Metropolis, Nigeria. Medical Sciences. 2019;7(11): 104.

[115] Mustapha A, Imir T. Detection of Multidrug-Resistance Gram-Negative Bacteria from Hospital Sewage in North East, Nigeria. Frontiers in Environmental Microbiology. 2019;5(1):1.

[116] Akinyemi KO, Oyefolu AOB, Mutiu WB, Iwalokun BA, Ayeni ES, Ajose SO, et al. Typhoid fever: tracking the trend in Nigeria. The American journal of tropical medicine and hygiene. 2018;99(3_Suppl):41–7.

[117] Eghieye M, Jodi S, Bassey B, Nkene I, Abimiku R, Ngwai Y. Antimicrobial resistance profile of Escherichia coli isolated from urine of patients in selected General Hospitals in Abuja Municipal, Nigeria. Asian Journal of Advanced Research and Reports. 2018:1–10.

[118] Osiyemi J, Osinupebi O, Ejilude O, Makanjuola S, Sunmola N, Osiyemi E. Antibiotic Resistance Profile of Methicillin-Resistant *Staphylococcus aureus* in Abeokuta, Nigeria. Journal of Advances in Microbiology. 2018:1–9.

[119] Onanuga A, Omeje MC, Eboh DD. Carriage of multi-drug resistant urobacteria by asymptomatic pregnant women in Yenagoa, Bayelsa State, Nigeria. African journal of infectious diseases. 2018;12(2):14–20.

[120] Alechenu EC, Nweze JA, Lerum NI, Eze EA. Prevalence and Antibiotic Resistance Patterns of Gram-Negative Uropathogens among Paediatric Patients in Nigeria. Open Journal of Medical Microbiology. 2019;9 (04):215.

[121] Adelowo OO, Caucci S, Banjo OA, Nnanna OC, Awotipe EO, Peters FB, et al. Extended Spectrum Beta-Lactamase (ESBL)-producing bacteria isolated from hospital wastewaters,

rivers and aquaculture sources in Nigeria. Environmental Science and Pollution Research. 2018;25(3):2744–55.

[122] Awogbemi J, Adeyeye M, Akinkunmi E. A Survey of Antimicrobial Agents Usage in Poultry Farms and Antibiotic Resistance in Escherichia Coli and Staphylococci Isolates from the Poultry in Ile-Ife. Journal of Infectious Diseases and Epidemiology. 2018;4(1).

[123] Kwoji I, Tambuwal F, Abubakar M, Yakubu Y, Musa J, Jauro S, et al. Antibiotic sensitivity patterns of methicillin-resistant staph-ylococcus aureus isolated from chickens in poultry farms in sokoto, nigeria. Adv Anim Vet Sci. 2018;6(1):8–11.

[124] Oloso NO, Fagbo S, Garbati M, Olonitola SO, Awosanya EJ, Aworh MK, et al. Antimicrobial resistance in food animals and the environment in Nigeria: A review. International journal of environmental research and public health. 2018;15(6):1284.

[125] Adamu MS, Ugochukwu ICI, Idoko SI, Kwabugge YA, Abubakar NSa, Ameh JA. Virulent gene profile and antibiotic susceptibility pattern of Shiga toxin-producing Escherichia coli (STEC) from cattle and camels in Maiduguri, North-Eastern Nigeria. Tropical animal health and production. 2018;50(6):1327–41.

[126] Onifade A, Afolami O. Antibiotic resistance patterns of Salmonella spp from clinical and water samples in Akure, Ondo State, Nigeria. Asian Journal of Research in Medical and Pharmaceutical Sciences. 2018:1–10.

[127] Abu G, Wondikom A. Isolation, characterization and antibiotic resistance profile studies of bacteria from an excavated pond in Port Harcourt Metropolis, Nigeria. Journal of Applied Sciences and Environmental Management. 2018;22(8):1177–84.

[128] Akaniro I, Oguh C, Kafilat K, Ahmed I, Ezeh C. Physicochemical properties, bacteriological quality and antimicrobial resistance profile of isolates from groundwater sources in ile-ife suburbs, Southwest Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2019; 13(1):58–65.

[129] Fowoyo P, Abuo G. Bacteriological Profiling and Antibiotic Resistance of Bacteria Isolated From River Niger Lokoja Tributary, Nigeria. Journal of Applied Life Sciences International. 2018:1–11.

[130] Akinyemi K, Ajoseh S, Iwalokun B, Oyefolu A, Fakorede C, Abegunrin R, et al. Antimicrobial resistance and plasmid profiles of *Salmonella enterica* serovars from different sources in Lagos, Nigeria. Health. 2018;10(6):758–72.

[131] Ajoke AO, Adetokunboh OA. Multiple-Antibiotic Resistance Pattern of Coliform Bacteria Isolated from Different Sources in Iwo, Nigeria. Open Science Journal of Bioscience and Bioengineering. 2018;5(3):41.

[132] Nyandjou Y, Yakubu S, Abdullahi I, Machido D. Multidrug resistance patterns and multiple antibiotic resistance index of salmonella species isolated from Waste Dumps in Zaria Metropolis, Nigeria. Journal of Applied Sciences and Environmental Management. 2019;23(1):41–6.

[133] Borges KA, Furian TQ, Souza SNd, Salle CTP, Moraes HLdS, Nascimento VPd. Antimicrobial resistance and molecular characterization of *Salmonella enterica* serotypes isolated from poultry sources in Brazil. Brazilian Journal of Poultry Science. 2019;21(1).

[134] Cunha-Neto Ad, Carvalho LA, Carvalho RCT, dos Prazeres Rodrigues D, Mano SB, Figueiredo EEdS, et al. Salmonella isolated from chicken carcasses from a slaughterhouse

in the state of Mato Grosso, Brazil: antibiotic resistance profile, serotyping, and characterization by repetitive sequence-based PCR system. Poultry science. 2018;97(4):1373–81.

[135] Moura Q, Fernandes MR, Silva KC, Monte DF, Esposito F, Dropa M, et al. Virulent nontyphoidal Salmonella producing CTX-M and CMY-2 β-lactamases from livestock, food and human infection, Brazil. Virulence. 2018;9(1):281–6.

[136] Almeida F, Seribelli AA, Medeiros MIC, dos Prazeres Rodrigues D, De MelloVarani A, Luo Y, et al. Phylogenetic and antimicrobial resistance gene analysis of Salmonella Typhimurium strains isolated in Brazil by whole genome sequencing. PloS one. 2018;13(8).

[137] da Cunha-Neto A, Carvalho LA, Castro VS, Barcelos FG, Carvalho RCT, Rodrigues DdP, et al. Salmonella Anatum, S. Infantis and S. Schwarzengrund in Brazilian Cheeses: occurrence and antibiotic resistance profiles. International Journal of Dairy Technology. 2020;73(1):296–300.

[138] Acharya KP, Wilson RT. Antimicrobial resistance in Nepal: a review. Frontiers in medicine. 2019;6:105.

[139] Shrivastava SR, Shrivastava PS, Ramasamy J. World health organization releases global priority list of antibiotic-resistant bacteria to guide research, discovery, and development of new antibiotics. Journal of Medical Society. 2018;32(1):76.

[140] Bartley PS, Domitrovic TN, Moretto VT, Santos CS, Ponce-Terashima R, Reis MG, et al. Antibiotic resistance in Enterobacteriaceae from surface waters in urban Brazil highlights the risks of poor sanitation. The American journal of tropical medicine and hygiene. 2019;100(6):1369–77.