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Determinants of indiscriminate antimicrobial use in commercial chicken farms in Bangladesh and their impact on food safety and public health

Mehedi Hasan[1], Tiasha Ali[1], A. K. M. Dawlat Khan[1], Monjurul Islam[1], Arif Khan[1], Abu Sayeed[2,7], Zulqarnine Ibne Noman[1,3], Abdullah Al Mamun[1], Shariful Islam[1,4], Mohammad Mahmudul Hassasn[5,6], Cameron E. F. Clark[7], Tahmina Shirin[1] & Ariful Islam[7,8,9]✉

Antimicrobial resistance (AMR), associated with irrational antimicrobial use (AMU) poses a significant health threat to both humans and animals. Thus, our research determined AMU patterns and their associated factors in Bangladeshi chicken farms. We conducted a cross-sectional study in 340 commercial chicken farms comprising broilers (109), layers (109), and Sonali (122) farms in seven districts of Bangladesh from September to October 2021. Data were collected using in-person interviews with a pre-tested semi-structured questionnaire. Statistical analyses were performed, including descriptive statistics to understand farmer demographics and AMU practices, a Chi-square test to evaluate farmers' knowledge, attitudes and practices (KAP), and logistic regression analysis to determine the factors associated with AMU. The findings indicated that 93.2% (317/340) farms administered at least one antimicrobial (AM) to chickens during the production cycle, with 67.0% of farmers used antimicrobials (AMs) in the 14 days before data collection. The usage of AMs was higher in meat-type chickens, such as broiler (78.0%) and Sonali (67.2%), in contrast to egg-type chickens, like layer (41.3%). The AMU practices were significantly associated with multiple factors, such as farming experience, poultry production type, knowledge gaps in proper AMU practices, the person managing the farm, reuse of left-over AMs, and compliance with veterinarians' recommendations. We highlight the indiscriminate use of AMs that is occurring in poultry industry in Bangladesh, which could result in AM residues and resistance, posing detrimental consequences for public health. Farmers training on increasing their KAP regarding AMU to protect animal health, human health, and the ecosystem, is urgently needed.

Keywords Poultry, AMR, AMU, Antimicrobial residues, KAP, Antimicrobial misuse

Abbreviations

AM	Antimicrobial
AMR	Antimicrobial resistance
AMU	Antimicrobial usage
AR	Antimicrobial residues

[1]Institute of Epidemiology, Disease Control and Research (IEDCR), Dhaka 1212, Bangladesh. [2]National Centre for Epidemiology and Population Health (NCEPH), Australian National University, Canberra, ACT 2601, Australia. [3]Infectious Diseases Division (IDD), icddr,b, 68, Shaheed Tajuddin Ahmed Sarani, Mohakhali, Dhaka 1212, Bangladesh. [4]Department of Fish and Wildlife Conservation, Virginia Tech, Blacksburg, VA, USA. [5]Faculty of Veterinary Medicine, Chattogram Veterinary and Animal Sciences University, Chattogram 4225, Bangladesh. [6]Queensland Alliance for One Health Sciences, School of Veterinary Science, The University of Queensland, Gatton, QLD 4343, Australia. [7]Gulbali Institute, Charles Sturt University, Wagga Wagga, NSW 2678, Australia. [8]Biosecurity Research Program and Training Centre, Gulbali Institute, Charles Sturt University, Wagga Wagga, NSW 2678, Australia. [9]Training Hub Promoting Regional Industry and Innovation in Virology and Epidemiology, Gulbali Institute, Charles Sturt University, Wagga Wagga, NSW 2678, Australia. ✉email: aislam@csu.edu.au

CI	Confidence interval
DLS	Department of Livestock Services
GLM	Generalized linear model
KAP	Knowledge, attitude, and practices
LASSO	Least absolute shrinkage and selection operator
MDR	Multidrug resistance
OR	Odds ratio
WHO	World Health Organization
WOAH	World Organization for Animal Health

Antimicrobials (AMs) are used for several purposes, including therapeutics, prophylaxis, and sometimes for growth promotion in livestock[1]. However, inappropriate use of AMs may cause antimicrobial resistance (AMR), one of the most significant threats to global health[2,3]. Although some studies indicate the existence of naturally resistant bacteria, excessive use of AMs is one of the main causes of the development and spread of AMR in livestock[1,4,5]. Indiscriminate antimicrobial usage (AMU) also can retain unacceptable levels of antimicrobial residues (AR) in animal-derived food, whose effects on consumer health can be more detrimental[6]. It is also evident that farmer's extensive reliance on AMs, inadequate awareness campaigns, poor farm-biosecurity, and a lack of education regarding AMU, AR and AMR are all factors can foster the problem[7–9]. Therefore, it becomes very important to evaluate and increase the knowledge and practice regarding AMU, AR and AMR among all the associated personnel from farms to consumers.

It is anticipated that Asia's AMU in chicken production will increase by 129% by 2030. Due to intensive farming practices, livestock production has greatly expanded in Bangladesh to supply the increasing population's demand for animal-origin proteins. Poultry farming in Bangladesh is emerging as a sustainable source of income for rural communities . According to the livestock economy of Bangladesh for the years 2023 to 2024, 327.7 million chickens were produced[10]. As a result, the usage of AMs is expanding quickly in Bangladesh, which raises the likelihood that AMU may continue to develop AMR and eventually spread to people through the food chain.

In addition to the effects on public health, a significant rise in resistance to routinely used AMs may lead to fewer treatment choices, and so cause significant production loss in livestock[1]. There are several studies on AMR in Bangladesh reporting a high percentage of multidrug resistance (MDR) in foodborne bacteria (74%, 98%, and 97% respectively in *E. coli*, *Salmonella spp*, and *Camplobacter spp*) from chicken cloacal swab samples[2,11,12]. Mandal, Talukder[2] and Talukder, Hasan[12] also found 76% and 81% resistant bacteria in farm sewage along with 79% and 91% in chicken handler's sample, respectively. Another study found that the *E. coli* isolates recovered from all the collected fecal and environmental samples from the chicken farms exhibited MDR[13]. A literature review analyzed that 45 different AMs from 14 different classes were reported with varying levels of resistance against *E. coli* isolated from poultry and their environments in Bangladesh[14]. Mandal, Talukder[2] identified the use of AMs without a veterinarian's prescription as a risk factor for *E. coli* infection in broilers with MDR bacteria. Moreover, the biosecurity measures in commercial poultry farms in Bangladesh are not well established. It causes frequent viral and bacterial infections, leading to increased AMU and AMR development, and indicates a significant lack of knowledge regarding proper farming practices[15–17]. The misuse of AMs linked to the lack of knowledge is one of the major factors contributing to the expansion of AMR[18]. In addition, some studies hypothesized that AMR bacterial emergence in poultry in Bangladesh can be caused by the haphazard use of AMs and their use as growth promoters at sub-therapeutic dosage[2,19].

Controlling AMU, monitoring resistance patterns, and coming up with alternatives to AMs are now essential to mitigate AMR in chicken farms. High-income countries have limited AMU in animals to address the emergence of AMR bacteria in livestock production system and reduce the risk of transmission to humans and livestock[20–22]. However, many low and middle-income countries including Bangladesh have yet to implement comprehensive restrictions on AMU in food animals due to poor regulation enforcement, which leads to drug abuse and the emergence of AMR[19,23,24]. Although a few studies have evaluated the farmer's knowledge, attitude, and practices (KAP) regarding AMU and AMR in Bangladesh[8,18,19,25], there remains a significant gap in understanding the specific factors driving irrational AMU, which is a major cause of AR and AMR development. Furthermore, it is crucial to explore how farmers' KAP affect initiatives to lower the use of AMs in farm animals. Most of the areas we investigated have remained unexplored for such a study considering their poultry population. Our study addresses these gaps by analyzing the trends in AMU and its associated factors in Bangladeshi commercial poultry farms. We also assess farmers' attitudes and practices regarding AMU, AR and AMR together to identify the potential drivers of AMR and pinpoint the necessary strategies to minimize public health risks.

Methods
Study period and areas
We conducted a cross-sectional study on commercial chicken farms of 24 upazilas (sub-districts) from 7 districts (Dhaka, Gazipur, Narsingdi, Narayanganj, Munshiganj, Manikganj, and Cox's Bazar) in Bangladesh from September to October 2021 (Fig. 1). The districts surrounding the capital city Dhaka were selected since the areas are well-known for having a higher poultry population, and are a crucial chicken-supplying area for the capital's approximately 2.24 million people[26,27]. Two major divisions of Bangladesh, Dhaka and Chattogram, account for 72.9% of the nation's total commercial chicken production[17]. The high concentration of farms in these areas is likely due to market demand and efficient transportation, making them suitable sampling sites to identify drivers for AMU[17]. Cox's bazar was included as a pilot site representing the Chattogram division, which produce the second highest poultry in Bangladesh. However, it was expected to have minimal impact on overall

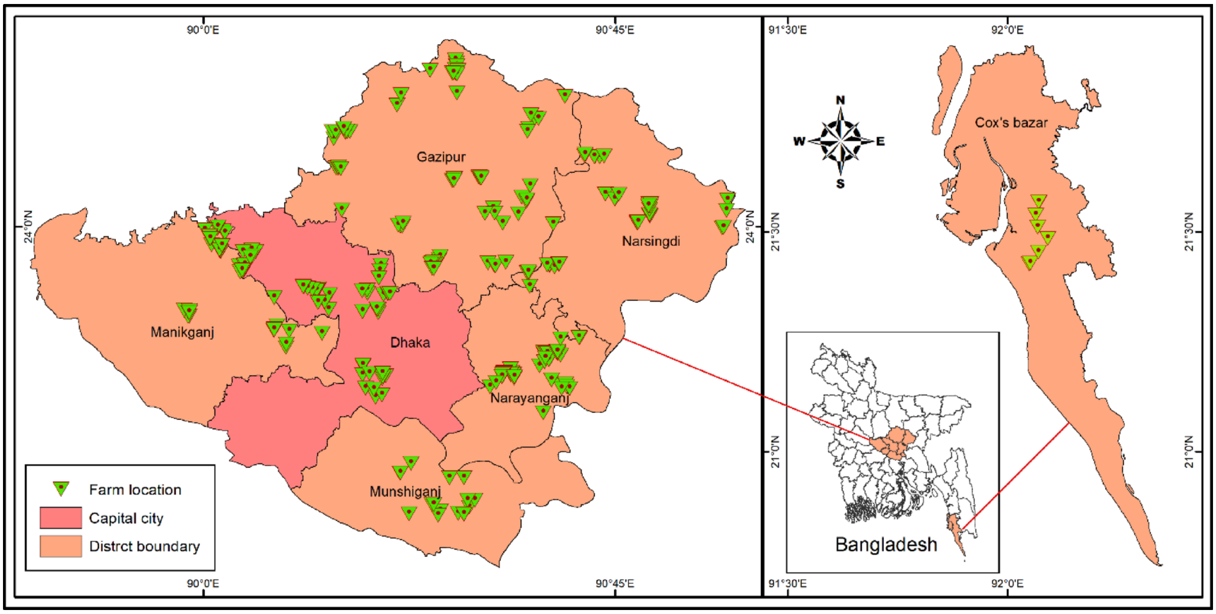

Fig. 1. Map of the studied district of Bangladesh in 2021. Pink colored region represent the capital city of Bangladesh. Triangles (green colored) indicate the location of commercial chicken farms.

results due to sampling a small number of farms. ArcMap 10.8 (ESRI, Redlands, CA, United States) was used to plot the farm locations throughout the study areas.

Study design and data collection

The required number of sample size was 340 assuming 33% prevalence with 95% confidence interval and 5% precision based on previous study[8,28]. We carried out this cross-sectional study on 340 small and medium-scale commercial broilers ($n=109$), layers ($n=109$), and Sonali and some other meat-type ($n=122$) chicken farms. Other meat types included a few cockerel chickens which had similar management and thus we described this category as Sonali to describe better throughout the article. We surveyed through a purposive sampling technique and collected a dissimilar number of farms from each district (Dhaka = 79, Gazipur = 78, Narsingdi = 50, Narayanganj = 61, Munshiganj = 25, Manikganj = 38, and Cox's Bazar = 9). The farm selection criteria were that the farmer should have had the complete information on the farm management and AMU. We collected data from the farmers through a face-to-face interview using a semi-structured questionnaire focused on both egg and meat production systems in Bangladesh. We informed the farmers about our study and took interviews upon their consent. Farmers who were unwilling to provide consent or who did not have enough time to participate in the study were not included in it.

Questionnaire design and interviews

We developed a questionnaire based on the relevant literature review and the expert's opinions. It was designed mostly with close-ended questions to make it easier to minimize data variation and improve the response precisions. The questionnaire comprised socio-demographic characteristics of chicken farmers: age, gender, main occupation, formal education, and farming experience; farm characteristics: type of the production system, age of chickens, chicken strains, flock size, number of sheds; knowledge and perceptions of farmers about AR and AMR in chickens and humans; AMU practices in chickens; and factors that affect farmers' misuse of AMs in their farms.

We collected data on current AM usage on the day of data collection, previous AM usage in 14 days preceding the interview, and AM usage since the beginning of the production cycle. We considered AM usage in the last 14 days from data collection focusing on that no AMs had withdrawal period more than 14 days unless exception. Additionally, we collected data on leftover AMs (AMs that are partially used in any previous treatment occurrence on that farm) to assess their potential impact on current practices and compliance. The questionnaire was drafted by the veterinarians in our research team and pretested by collecting data from the farmers. Based on the pretest results, it was revised to ensure practicality and alignment with the real-world scenario. Then the questionnaire was reviewed by the entire research team members to improve its accuracy and minimize biases.

We collected data based on information provided by farmers. However, data on AMU practices, including the names, dosage, and frequency were recorded upon looking at the AM packages, drug record book, and prescriptions available at the farms. Additionally, we conducted interviews with key farm workers and owners who were directly involved in the administration of the chicken flocks.

Data management and analysis

We summarized all participants' responses in Microsoft Excel Professional Plus 2021 (Microsoft Corporation, Redmond, WA, USA) spreadsheets, and analyzed them using R software version 4.3.1. The frequency of farmer demographics and AMU practices were analyzed using descriptive statistics. Farmers' overall KAP regarding AMU, AR, and AMR and their relationships with different production systems were analyzed using the Chi-square test at a 95% confidence level. Additionally, we categorized eight AMU-related practices as either "good practice" if their farm management aimed at mitigating AR and AMR emergence, or "inappropriate practice" if they were in opposite direction. Each practice-related categorical variable was scored as 0 (inappropriate practice), or 1 (good practice), resulting in an overall response score ranging from 0 to 8 for each participant (Supplementary Fig. 1). Participants were then classified by the following total outcome scores: "poor practice" refers to the respondents whose total scores falls between 0 and 4, while "good practice" refers to those scoring between 5 and 8 points.

The source of AMs (veterinary medical stores, feed and chick traders), the purpose of usage, farm characteristics (farm type, flock size), and farmer characteristics (education, experience in poultry farming) were all taken into consideration to determine whether using AMs in the last 14 days preceding the day of data collection were associated with those or not (Supplementary Table 1). Due to large number of variables, least absolute shrinkage and selection operator (LASSO) regression was used to assess the relative importance of numerous predictor variables in our study. The LASSO regression is an adaptation of the generalized linear model (GLM) and it effectively minimizes prediction error for datasets with multiple predictor variables[29]. The model identifies subsets of predictors that were associated with the outcome of interest by applying a shrinkage operation to regression coefficients, shrinking some coefficients to exactly zero[30]. We repeated the model using bootstrapping to calculate bootstrap support, i.e., the proportion of times a predictor variable is selected in the model as the LASSO does not generate confidence intervals[31–33]. We ran LASSO regressions using the "glmnet" package in R[34].

A separate logistic regression model was used to determine factors associated with AMU practices. We initially performed univariate analysis between independent factors and AMU practices to select those variables with p-value less than 0.2 (Supplementary Table 2). However, not all variables were included in the final model due to multicollinearity between independent variables. Cramer's V was used to check multicollinearity between the independent variables, and several variables were excluded from the model due to a high value (>0.4) of Cramer's V[35] (Supplementary Fig. 2).

Results

Overview of the demographic characteristics

Among the 340 farms studied, broiler and layer farms were equally shared (32.1%) and the rest (35.9%) were Sonali (Table 1). Meat type chicken such as broiler and Sonali were mainly raised on small-scale, while 50.5% of layer farms operated within medium-scale range. The median flock size was 1498 (Supplementary Fig. 3). Most of the broiler (78.9%) and Sonali (68.0%) farm owners raised their chickens by themselves without any workers, whereas 68.8% of layer farms had worker involvement (Table 1). Overall, there was a predominance of male farmers (94.4%) in poultry farming, and only 14.4% had training in poultry management. The majority of

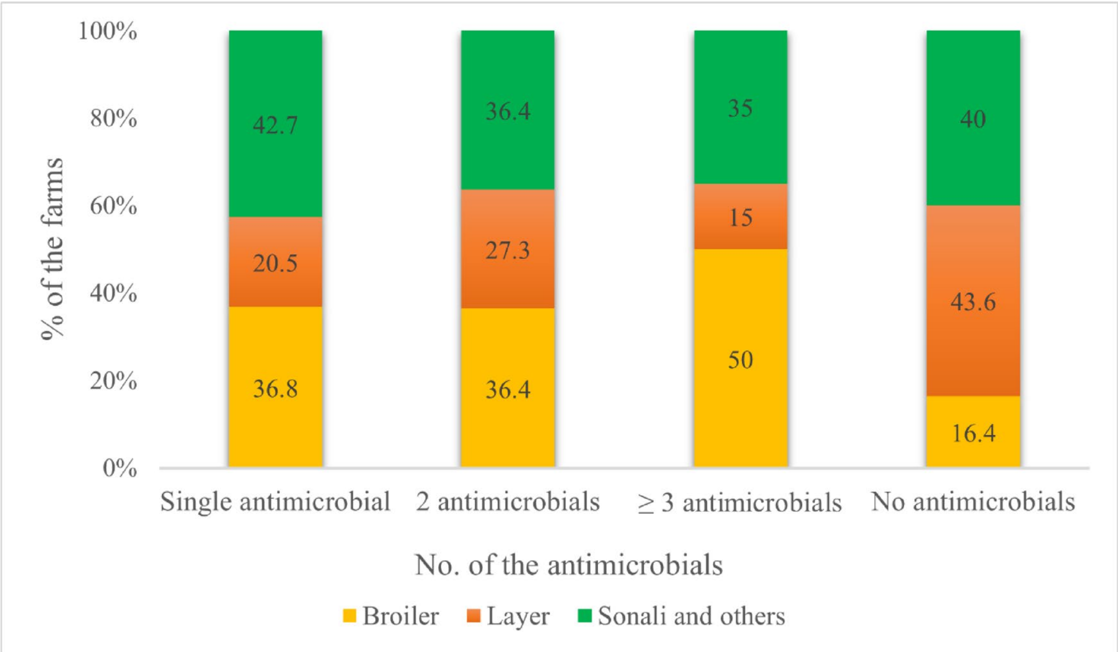

Fig. 2. Number of AM classes used in commercial chicken farms within the last 14 days of data collection.

Variables	Broiler farms, *n* = 109; % (95% CI)	Layer farms, *n* = 109; % (95% CI)	Sonali farms, *n* = 122; % (95% CI)	Total, *n* = 340; % (95% CI)	*P*-value
Farm size					
Small scale (≤ 2000 birds)	89.9 (82.7–94.9)	49.5 (39.8–59.3)	63.1 (53.9–71.7)	67.4 (62.1–72.3)	< 0.001
Medium scale (> 2000 birds)	10.1 (5.1–17.3)	50.5 (40.7–60.2))	36.9 (28.3–46.1)	32.6 (27.7–37.9)	
Working personnel on the farm					
Owner	78.9 (70.0-86.1)	31.2 (22.7–40.8)	68.0 (59.0-76.2)	59.7 (54.3–65.0)	< 0.001
Worker	8.3 (3.1–15.1)	44.0 (34.5–53.9)	18.0 (11.7–26.0)	23.2 (18.5–28.1)	
Both owner and worker	12.8 (7.2–20.6)	24.8 (17.0–34.0)	13.9 (8.3–21.4)	17.1 (13.2–21.5)	
Age of farmers					
18–30 years	35.8 (26.8–45.5)	22.0 (14.6–31.0)	31.1 (23.1–40.2)	29.7 (24.9–34.9)	0.205
31–40 years	26.6 (18.6–35.9)	35.8 (26.8–45.5)	37.6 (25.3–42.7)	32.1 (27.1–37.3)	
> 40 years	37.6 (28.5–47.4)	42.2 (32.8–52.0)	35.2 (26.8–44.4)	37.1 (33.0-43.6)	
Gender of farmers					
Male	89.0 (3.0-81.6)	98.2 (93.5–99.8)	95.9 (90.7–98.)	94.4 (91.4–96.6)	0.009
Female	11.0 (5.8–18.4)	1.8 (0.2–6.5)	4.1 (1.3–9.3)	5.6 (3.4–8.6)	
Educational status of farmers					
Illiterate or primary educated	20.2 (13.1–28.9)	26.6 (18.6–35.9)	27.0 (19.4–35.8)	24.7 (20.2–29.6)	0.327
Secondary or higher secondary educated	69.7 (60.2–78.2)	56.9 (47.0-66.3)	59.8 (50.6–68.6)	62.1 (56.7–67.2)	
Graduated or post graduated	10.1 (5.1–17.3)	16.5 (10.1–24.8)	13.1 (7.7–20.4)	13.2 (9.8–17.3)	
Main occupation of the farmers					
Poultry farming	56.9 (47.0-66.3)	56.0 (46.1–65.5)	63.1 (54.0-71.7)	58.8 (53.3–64.1)	0.481
Other than poultry	43.1 (33.7–53.0)	44.0 (34.5–53.9)	36.9 (28.3–46.1)	41.2 (35.9–46.6)	
Farming experience					
< 1–5 year	48.6 (38.9–58.4)	30.3 (21.8–39.8)	56.6 (47.3–46.0)	45.6 (40.2–51.0)	< 0.001
> 5–10 years	24.8 (17.0–34.0)	41.3 (31.9–51.1)	18.9 (12.3–26.9)	27.9 (23.2–33.0)	
> 10 years	26.6 (18.6–35.9)	28.4 (20.2–37.9)	24.6 (17.2–33.2)	26.5 (21.9–31.5)	
Training of the farmers					
Yes	14.7 (8.6–22.7)	15.6 (9.4–23.8)	13.1 (7.7–20.4)	14.4 (10.9–18.6)	0.862
No	85.3 (77.3–91.4)	84.4 (76.2–90.6)	86.9 (79.6–92.3)	85.6 (81.4–89.1)	

Table 1. Socio-demographic characteristics of commercial chicken farms and farmers in Bangladesh.

farmers had less than 5 years of farming experience, with 48.6% in broiler farms and 56.6% in Sonali farms. Only 26.5% of poultry farmers had over 10 years of farming experience.

Antimicrobial usage in farms

About 93% of our studied farms used at least one AM at any time during the rearing production cycle. We classified these AMs according to the World Health Organization's[36] priority classification of AMs (Table 3). We found that fluoroquinolones, tetracyclines, sulfonamides, penicillins, and macrolides were the most frequent AM classes used with a percentage of 45.7%, 35.2%, 25.5%, 23.9%, and 18.6%, respectively. Considering individual agents, a substantial percentage of farmers used 12 different AMs, including colistin (3.6%), erythromycin (8.5%), enrofloxacin (12.1%), and ciprofloxacin (21.5%), which belong to the WHO's highest priority critically important AMs class. Moreover, amoxicillin (23.9%), doxycycline (17.0%), oxytetracycline (16.6%), and neomycin (10.9%) were the most common AMs used by the farmers, while pefloxacin, chloramphenicol, and tetracycline were the least common AMs which shared the same percentage (0.4%). According to WHO AWaRe (access, watch, reserve) classification of AMs for evaluation and monitoring of use 2023[37], one reserve group AM and 12 watch group AMs were used in the farms (Supplementary Table 3). Furthermore, we found that frequently used 19 of the 31 AMs were Veterinary Critically Important Antimicrobial Agents (Supplementary Table 4), as classified by World Organization of Animal Health[38].

Out of the 340 farmers, 247 properly responded to the names, dosage, frequency, and duration of the AMs administered on their farms. Among these 247, about half (47.4%) had used at least one class of AM within the preceding 14 days of data collection, where broiler, layer, and Sonali were 36.8%, 20.5%, and 42.7% respectively (Fig. 2). It is worrisome that 50% of the broiler farms administered ≥ 3 classes of AMs during rearing period even though their lifecycle is the shortest one. In contrast, layer farmers (43.6%) were less likely to use AMs in the last 14 days, compared to broiler (16.4%).

Overall, broiler farms shared the highest percentage of AM classes compared to Sonali and layers during the 14-day period before data collection (Fig. 3). Among the fluoroquinolones, the most used AM was used on farms; 42.7% were broilers. Likewise, 42.9% of penicillin users, 40.7% of aminoglycoside users, and 40% of macrolides users were broiler farmers. However, 100% of the nitroimidazoles and lincosamides, along with 75% of first-generation cephalosporins, were also used by broiler farmers. Sonali shared the highest percentage of

WHO priority to antimicrobial class	Antimicrobial class (n, % of farms) ($N=247$)	Antimicrobial	n (%) of farms ($N=247$) [a]
Highest Priority Critically Important Antimicrobials	Macrolides and ketolides (46, 18.6)	Azithromycin	4 (1.6)
		Erythromycin	21 (8.5)
		Tilmicosin	8 (3.2)
		Tylosin	13 (5.3)
	Polymyxins (9, 3.6)	Colistin	9 (3.6)
	Quinolones and Fluoroquinolones (113, 45.7)	Ciprofloxacin	53 (21.5)
		Enrofloxacin	30 (12.1)
		Flumequine	4 (1.6)
		Levofloxacin	14 (5.7)
		Moxifloxacin	5 (2.0)
		Norfloxacin	6 (2.4)
		Pefloxacin	1 (0.4)
High Priority Critically Important Antimicrobials	Aminoglycosides (32, 12.9)	Gentamicin	5 (2.0)
		Neomycin	27 (10.9)
	Penicillins (aminopenicillins) (59, 23.9)	Amoxicillin	59 (23.9)
Highly Important Antimicrobials	Amphenicols (15, 6.1)	Chloramphenicol	1 (0.4)
		Florfenicol	14 (5.7)
	Cephalosporins (1st and 2nd generation) and cephamycins (5, 2.0)	Cefalexin	5 (2.0)
	Lincosamides (3, 1.2)	Lincomycin	3 (1.2)
	Sulfonamides (63, 25.5)	Sulfachlorpyridazine	4 (1.6)
		Sulfadiazine	21 (8.5)
		Sulfadimidine	3 (1.2)
		Sulfamethoxazole	3 (1.2)
		Sulfaquinoxaline	1 (0.4)
		Trimethoprim	31 (12.6)
	Tetracyclines (87, 35.2)	Chlortetracycline	3 (1.2)
		Doxycycline	42 (17.0)
		Oxytetracycline	41 (16.6)
		Tetracycline	1 (0.4)
Important Antimicrobials	Nitroimidazoles (2, 0.8)	Metronidazole	2 (0.8)
	Pleuromutilins (7, 2.8)	Tiamulin	7 (2.8)

Table 2. Frequency distribution of the AMs used during production cycle in the commercial chicken farms in Bangladesh. [a] Farms included in the table that had correct information on the antibiotic names.

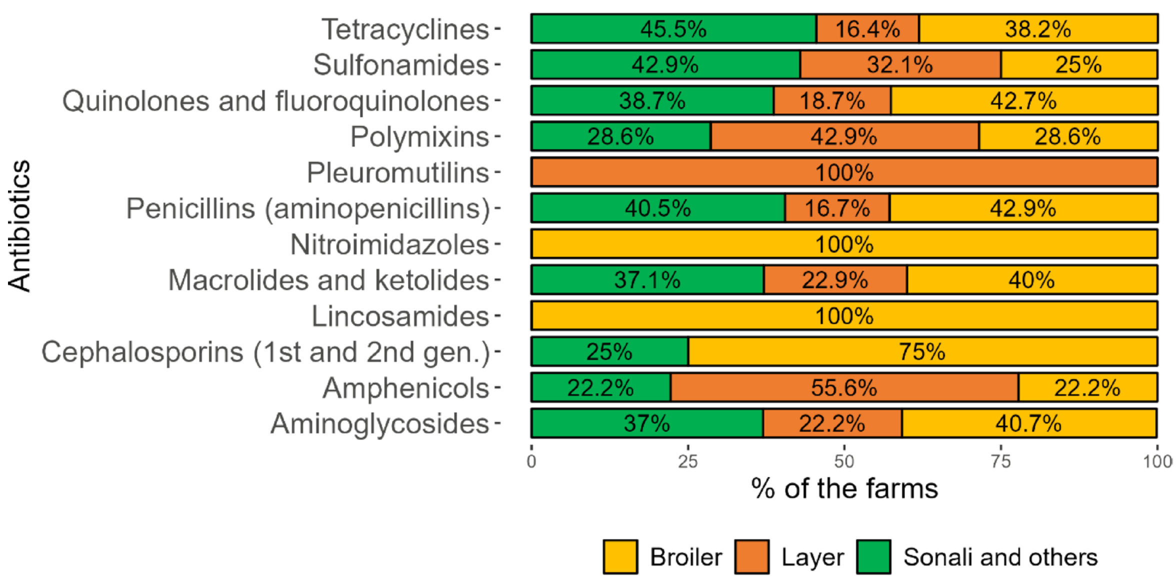

Fig. 3. AM classes used in the commercial chicken farms within the last 14 days of data collection.

	No. (%) of the farms				***P*-value**
Variables	**Broiler, *n* = *109***	**Layer, *n* = *109***	**Sonali, *n* = *122***	**Total, *N* = *340***	
Knowledge					
Do farmers know about AMR?					
Yes	33 (30.3)	43 (39.4)	31 (25.4)	107 (31.5)	0.068
No	76 (69.7)	66 (60.6)	91 (74.6)	233 (68.5)	
Attitudes					
Do farmers think that AMs can be given to poultry at any time?					
Yes	49 (45.0)	30 (27.5)	64 (52.5)	143 (42.1)	**0.03**
No	55 (50.5)	75 (68.8)	54 (44.3)	184 (54.1)	
Unknown	5 (4.6)	4 (3.7)	4 (3.3)	13 (3.8)	
Do farmers think that vaccination can reduce AMs use?					
Yes	68 (62.4)	83 (76.1)	92 (75.4)	243 (71.5)	**0.015**
No	23 (21.1)	22 (20.2)	19 (15.6)	64 (18.8)	
Unknown	18 (16.5)	4 (3.7)	11 (9.0)	33 (9.7)	
Do farmers think AMU in chickens may have side effects?					
Yes	56 (51.4)	61 (56.0)	56 (45.9)	173 (50.9)	0.292
No	16 (14.7)	22 (20.2)	23 (18.9)	61 (17.9)	
Unknown	37 (33.9)	26 (23.9)	43 (35.2)	106 (31.2)	
Do farmers think that AM residue can remain in eggs and meat?					
Yes	50 (45.9)	58 (53.2)	53 (43.4)	161 (47.4)	**0.001**
No	44 (40.4)	41 (37.6)	34 (27.9)	119 (35.0)	
Unknown	15 (13.8)	10 (9.2)	35 (28.7)	60 (17.6)	
Do farmers think that AM residues are destroyed during cooking?					
Yes	29 (26.6)	35 (32.1)	47 (38.5)	111 (32.6)	0.365
No	32 (29.4)	28 (25.7)	33 (27.0)	93 (27.4)	
Unknown	48 (44.0)	46 (42.2)	42 (34.4)	136 (40.0)	
Do farmers think that AM residue can pass to humans					
Yes	45 (41.3)	36 (33.0)	49 (40.2)	130 (38.2)	0.578
No	15 (13.8)	16 (14.7)	21 (17.2)	52 (15.3)	
Unknown	49 (45.0)	57 (52.3)	52 (42.6)	158 (46.5)	
Practices					
Purpose of the AM usage (*N* = 317)					
Therapeutic	48 (47.5)	64 (62.7)	48 (42.1)	160 (50.5)	**0.008**
Prophylactic	38 (37.6)	28 (27.5)	49 (43.0)	115 (36.3)	
Brooding	15 (14.9)	10 (9.8)	17 (14.9)	42 (13.2)	
Duration of the AM usage (*N* = 317)					
< 5 days	62 (61.4)	35 (34.3)	54 (47.4)	151 (47.6)	**0.001**
≥ 5 days	39 (38.6)	67 (65.7)	60 (52.6)	166 (52.4)	
Using multiple AMs at the same time					
Yes	40 (36.7)	36 (33.0)	47 (38.5)	123 (36.2)	0.634
No	60 (55.0)	59 (54.1)	66 (54.1)	185 (54.4)	
Unknown	9 (8.3)	14 (12.8)	9 (7.4)	32 (9.4)	
Farmers take the suggestion for using AMs from					
Veterinarians	25 (22.9)	53 (48.6)	41 (33.6)	119 (35.0)	**< 0.001**
Non-veterinarians	51 (46.8)	24 (22.0)	39 (32.0)	114 (33.5)	
Self-decision	33 (30.3)	32 (29.4)	42 (34.4)	107 (31.5)	
Using AMs on Day-Old-Chicks					
Yes	52 (47.7)	47 (43.1)	65 (53.3)	164 (48.2)	0.65
No	45 (41.3)	49 (45.0)	44 (36.1)	138 (40.6)	
Unknown	12 (11.0)	13 (11.9)	13 (10.7)	38 (11.2)	
Buying AMs with prescription					
Yes	26 (23.9)	40 (36.7)	40 (32.8)	106 (31.2)	**0.002**
No	58 (53.2)	34 (31.2)	63 (51.6)	155 (45.6)	
Both	25 (22.9)	35 (32.1)	19 (15.6)	79 (23.2)	
What do the farmers do when AMs do not respond within 3 days of treatment?					
Complete the course first	11 (10.1)	15 (13.8)	14 (11.5)	40 (11.8)	**< 0.001**
Continued					

	No. (%) of the farms				*P*-value
Contact with veterinarian	37 (33.9)	68 (62.4)	48 (39.3)	153 (45.0)	
Contact with feed and drug seller	22 (20.2)	1 (0.9)	16 (13.1)	39 (11.5)	
Increase dose/change the AMs by self	27 (24.8)	18 (16.5)	32 (26.2)	77 (22.6)	
Never face such a problem	12 (11.0)	7 (6.4)	12 (9.8)	31 (9.1)	
Farmers use left-over AMs					
Yes	44 (40.4)	28 (25.7)	40 (32.8)	112 (32.9)	0.07
No	65 (59.6)	81 (74.3)	82 (67.2)	228 (67.1)	
Farmers stop using AMs before marketing birds					
Yes	80 (73.4)	59 (54.1)	85 (69.7)	224 (65.9)	**0.006**
No	29 (26.6)	50 (45.9)	37 (30.3)	116 (34.1)	

Table 3. Knowledge, attitudes, and practices of the poultry farmers regarding AMU, AR and AMR.

Predictors		Odds ratio	95% C.I.	*P*-value
Type of poultry	Broiler	3.34	1.66–6.70	**0.001**
	Sonali	2.51	1.29–4.88	**0.007**
	Layer	Ref		
Age of farmers	31 to 40 years	0.85	0.46–1.60	0.62
	41 to 50 years	0.74	0.36–1.49	0.39
	> 50 years	2.25	0.91–5.60	0.08
	18 to 30 years	Ref		
Farming experience	5 to 10 years	1.02	0.55–1.86	0.96
	> 10 years	2.52	1.25–5.08	**0.01**
	≤ 5 years	Ref		
Who manage the farm	Owner	0.93	0.47–1.84	0.83
	Both	1.32	0.56–3.07	0.52
	Worker	Ref		

Table 4. Logistic regression model of the factors associated with AMU practice of farmers during 14 days preceding data collection.

pleuromutilins (100%), amphenicols (55.6%), and polymixins (42.9%), while the layer farmers used most of the tetracyclines (45.5%) and sulfonamides (42.9%).

Knowledge, attitudes, and practices of the poultry farmers regarding antimicrobial

The chi-square test results demonstrated that the farmers' overall KAP regarding AMU, AMR, and AR often varied depending on type of chickens in the farm (Table 4). Only 31.5% of farmers were aware of AMR, which is substantially associated with inappropriate AMU. A significantly higher percentage of broiler (45%) and Sonali (52.5%) chicken farmers, compared to layer (27.5%) farmers, believed they could administer AMs to their flocks at any time. In terms of AMU practice, 62.7% of layer farmers used AMs for therapeutic purpose, but they often did not complete the duration of suggestive dosage. On the other hand, 46.8% of broiler farmers took suggestions from non-veterinary sources, and 30.3% of farmers relied on their own decision regarding AMU.

We identified the frequency of the farmers taking suggestions for using AMs anytime from different sources, such as drug sellers, feed dealers, other farmers, and expert veterinarians (Fig. 4). Overall, 22.0% of farmers always looked for veterinarians, whereas 30.0% of farmers never went to a veterinarian for an AM prescription. Layer farmers (39.0%) were the most likely to follow veterinarian's suggestions all the time, followed by Sonali (19.0%), and broilers (10.0%). Besides, 92.0% of layer farmers reported seeking veterinarians from sometimes to always during the chicken rearing period, while 41.0% of broiler and 38.0% of Sonali farmers never go to veterinarians. In contrast, irrespective of the production type, about half or more farmers tended to use AMs by themselves but varied in frequency. Eighteen percent of both broiler and Sonali farmers always used AMs of their own choice, and it was 10% in the case of layers.

In a part of the interview, we asked farmers why they usually use AMs on chickens and presented the findings in Fig. 5. Interestingly, most farmers did not know the actual reason behind their AMs use on their chickens. About 37% of the respondents had no idea about why bacteria become resistant to AMs. More than a quarter (27.9%) of the farmers claimed that they used AMs to treat and prevent any kind of disease in their chickens, whereas only 6.2% of farmers used AMs to treat and prevent bacterial diseases. However, one-fifth (20.9%) of farmers mentioned that they used AMs for both viral and bacterial disease treatment and prevention. Even 10.3% of farmers used AMs for non-infectious diseases and 9.1% administered them even without knowing the reason behind it.

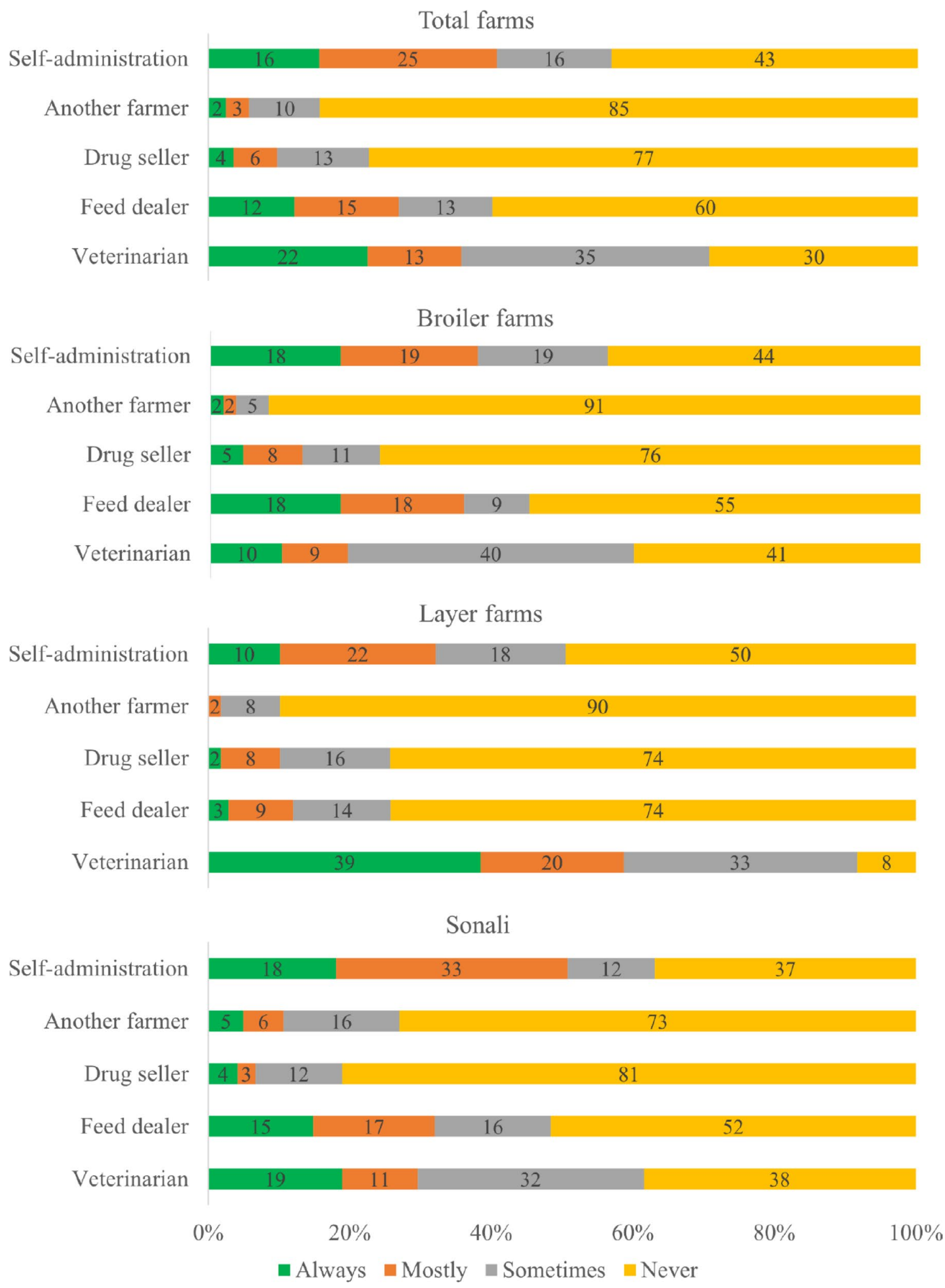

Fig. 4. Frequency of taking expert suggestions anytime to treat chickens on the commercial farms in Bangladesh.

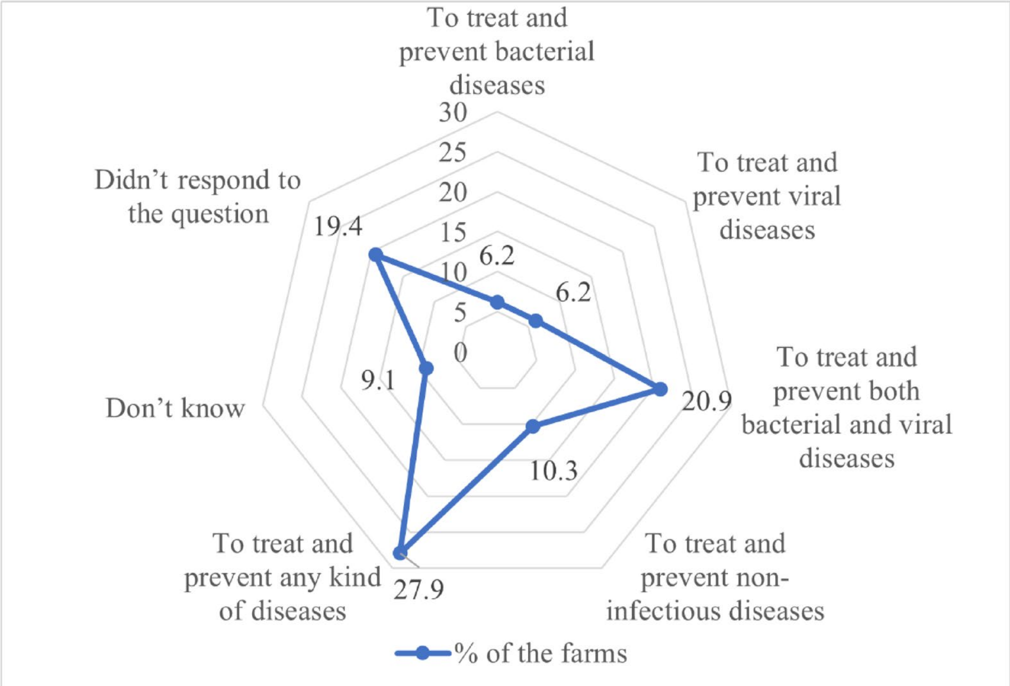

Fig. 5. Reasons behind the AMU on poultry in commercial poultry farm in Bangladesh.

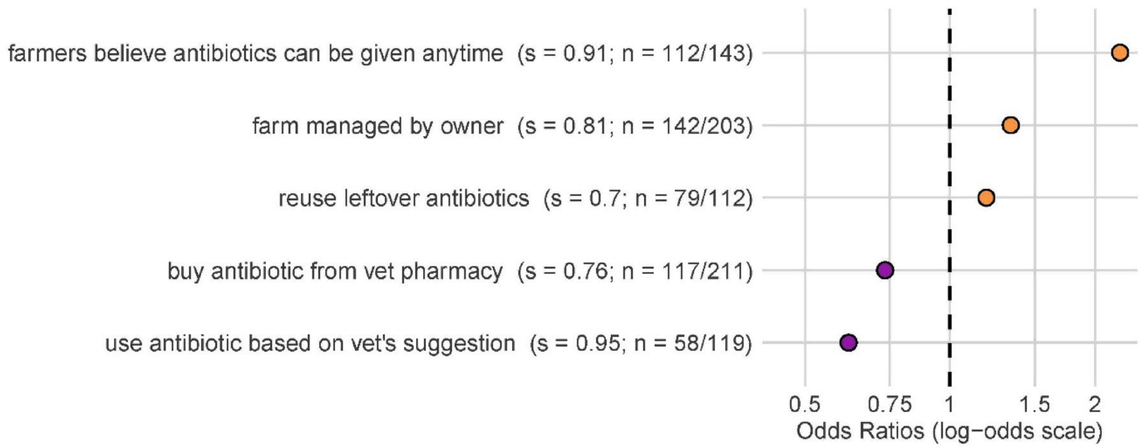

Fig. 6. Most relevant predictors of using AMs within last 14 days of data collection. *s* bootstrap support, *n* count positive. Bootstrap support values ≥ 0.6 are reported here, Odds ratio (OR) > 1 are positively associated and Odds ratio < 1 are negatively associated with the outcome.

Factors associated with antimicrobial usage and practice in last 14 days

The LASSO regression found three relevant factors that were positively associated with the use of AMs in last 14 days before data collection: farmers who believed that AMs can be used at any time (OR = 2.07, s = 0.91), farms that are managed by the owner (OR = 1.34, s = 0.81) and farms that used left-over AMs (OR = 1.16, s = 0.64) (Fig. 6). Two salient factors were negatively associated with AMs used: purchasing AMs from veterinary pharmacy rather than from feed dealers (OR = 0.78, s = 0.67), and seeking advice from veterinarians rather than non-veterinary persons (OR = 0.67, s = 0.89).

The logistic regression analysis showed that the "type of poultry" and the "farming experience of farmers" were significantly associated with their practices regarding AMU during the 14 days period before data collection (Table 4). The odds of poor AMU practice were 3.34 times (C.I. 1.66–6.70) higher in broiler farms and 2.51 times (C.I. 1.29–4.88) higher in Sonali farms than layers. The predictive risk in marginal mean analysis also underscores that 80% of broiler farms had a chance of poor practice where it was 75% in Sonali farms (Fig. 7A). Additionally, farmers with more than 10 years of farming experience were 2.52 times (C.I. 1.25–5.08) more likely to engage in poor practice than those with less than 5 years of experience (Table 4). The marginal mean indicates

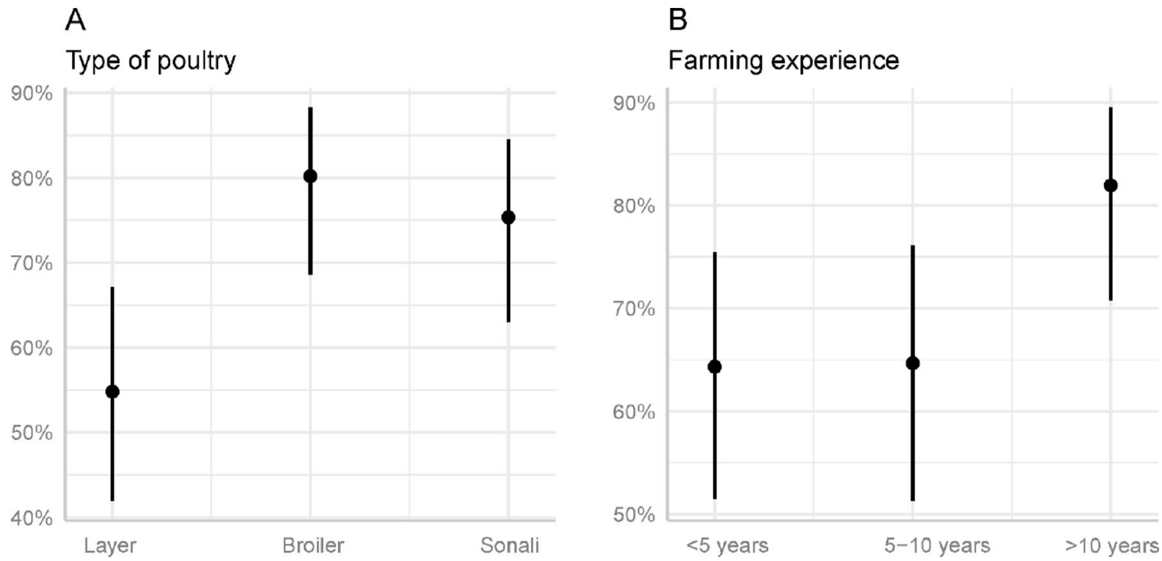

Fig. 7. Estimated marginal means (predicted values adjusted for all other effects) and their 95% confidence intervals for significant explanatory variables of full logistic regression model.

an 82% predictive risk of poor practices among farmers with more than 10 years of experience in farming while it was 64% for those with less than 5 years of experience (Fig. 7B).

Discussion

This study investigated a significant number of commercial chicken farms in Bangladesh, including various chicken production systems and scales, in the surrounding area of the country's capital. A key finding was the widespread use of critically important antimicrobials (CIAs), particularly fluoroquinolones and macrolides, which are considered highest priority by WHO. Nearly half of the farms used fluoroquinolones, and one-fourth used macrolides and penicillin. Another important observation was that owner-managed farms, permissive beliefs around AMU, and use of leftover AMs were positively associated with AM use. On the contrary, seeking advice from veterinarians and purchasing AMs from veterinary pharmacies were negatively associated with AMU. These findings underscore the need for improved veterinary oversight and regulated AM access in the poultry sector. This study also classified farmers' AM practices into "good" and "poor," with broiler and Sonali farms, as well as those with over 10 years of farming experience, significantly more likely to engage in poor practices. These findings highlight the need to prioritize these groups for targeted intervention.

Most farmers in this study were male (90%), untrained (14%), and predominantly decision-makers in the poultry sector. Only 35% consulted veterinarians, while many relied on informal sources like feed or medicine dealers. This trend reflects the dominant influence of non-veterinary personnel on AMU decisions. Additionally, a lack of proper training corresponding to poorer knowledge of correct AM dosage and withdrawal periods restricts their understanding of indiscriminate AMU[19].

The association between farming experience and poorer farming practices was unexpected. This occurrence in Bangladesh might be caused by limited access to current knowledge, aptitude for self-management, and eventually reliance on outdated practices. Many farmers exhibited insufficient knowledge of AMR and AMU despite years of experience, highlighting that experience alone cannot offer accurate understanding of these crucial issues[18]. This emphasizes the importance of continued education and targeted interventions, like peer-to-peer learning projects, and regular updates on AMU legislation and AMR threats.

In Bangladesh, between 54% and 100% of broiler and layer farms used AMs throughout their whole production cycle[19,25,39]. This study estimated that 93% of poultry farms used at least one AM during the rearing period, reinforcing the consistency with previous study. In the broader South and Southeast Asian context, AMU in commercial poultry farms ranged from 44 to 100% including countries like Pakistan, India, Thailand, and Vietnam[7,8]. Fluoroquinolones and tetracyclines are frequently used AMs in Bangladeshi poultry production, aligning with this study, due to their broad-spectrum activity, availability, and efficacy against bacterial infections[8].

Widespread use of AMs is associated with AMR development against the respective AMs[40]. For instance *E. coli* isolates from Bangladeshi poultry had high levels of resistance to tetracyclines (17.7% – 100%) and fluoroquinolones (5.9% – 100%) that support the finding of their excessive use[14]. The misuse and overuse of these AMs in poultry farming not only threatens animal health but also poses a significant public health risk through potential transmission of resistant bacteria via the food chain[14,41].

Several AMs used in the studied farms, such as doxycycline, oxytetracycline, amoxicillin, neomycin, erythromycin, tylosin, ciprofloxacin, and enrofloxacin, are listed on the World Organization for Animal Health (WOAH) list of AM agents of veterinary importance[42]. Some of the AMs including fluoroquinolones and the third and fourth generations of cephalosporins are regarded as being of CIAs for both human and animal health where WHO advised that colistin, and fluoroquinolones be restricted from prophylactic use in food animals[43,44].

Unexpectedly, many countries—including Bangladesh—still report using WHO-restricted AMs in poultry production[8]. This study confirmed that a substantial proportion of broiler, layer, and Sonali farms used WHO's Highest Priority CIAs, such as colistin, macrolides, and fluoroquinolones—reflecting similar trends reported by other studies in the region[45]. The regular use of these AMs can significantly contribute to the development and spread of AMR from animals to humans through the food chain[46,47].

This study revealed a widespread prophylactic AMs use, a global concern linked to growth promotion in poultry. Previous studies in Bangladesh also highlighted similar practices in commercial chicken production systems[19,28]. This study estimated that about 47.4% of farmers had used at least one AM within 14 days prior to data collection. In comparison, a recent study showed that AMs were used in 62% of broiler flocks on day one, and another 35% on day two of the production cycle, while 98% of Sonali flocks received treatment on day one[7]. We observed that 36.3% of farmers used AMs for prophylactic purposes, while previous studies in Bangladesh reported a range of 20–55% depending on production type and study design[8,28,48]. Routine prophylactic AM use across various phases of production has also been reported in other neighboring Asian countries[49–51]. This variations may reflect different study areas, poultry types, and sampling strategies.

Almost half of the farmers in this study administered AMs to day-old-chicks (DOC). A similar finding was reported in other study in this country[8], and across nine European countries, where 62% of broiler flocks received AMs on day one, and another 35% on day two of production[52]. In Sonali flocks, treatments were initiated on day one in 98% of the flocks[7]. The intensive nature and poor biosecurity practices in poultry farming in Bangladesh increase the disease susceptibility in DOCs, promoting early AMU. Additionally, farmers indebted to poultry dealers often follow the dealer's AM regimen from the first day of rearing[53].

Again, layer farmers were more likely to use AMs for therapeutic purposes (62.7%) and more frequently consulted veterinarians (48.6%) than broiler or Sonali farmers. Moreover, they were the least likely to rely on self-decision-making regarding AMU. These findings suggest that layer farmers generally exhibit better AM stewardship, which could be used as a model for AMU improvement strategies in other farm types.

Regarding KAP, about 31% of farmers were aware of AMR, which may have significant impacts on the risk of inappropriate AMU, incorrect dosage, and a lack of understanding of adverse effects[54]. To address this knowledge gap, promote prudent AMU practices, and eventually lower the risk of AMR transmission, targeted educational campaigns along with awareness initiatives are essential. This study estimated that 65% of farmers do not take recommendations from veterinarians on the use of AMU. Instead, they rely heavily on informal sources such as feed dealers, which not only undermines proper drug use but also perpetuates poor biosecurity practices. Transportation constraints and limited veterinary access in rural areas further discourage consultation with veterinarians[55]. Farmers often have financial dependencies on feed dealers, who sometimes push AMs sales for business gain[56]. Such dynamics lead to increased AMU and undermine regulatory control.

Similarly, owner-managed farms were more likely to use AMs due to their autonomous decision-making and focus on maximizing short-term profit. To reduce inappropriate AMU, recommendations from unqualified sources must be restricted[19]. Again, using left-over AMs was another common practice, observed in 32.9% of farms. This behavior is often based on the belief that previously effective drugs can be reused for similar symptoms. Similar practices were found in Pakistan and Indonesia[57,58]. Reliance on self-management, especially among experienced farmers, may reinforce this habit.

Although 65.9% of farmers stopped using AMs before marketing the birds, this was largely a cost-saving measure rather than an effort to respect withdrawal periods. While 37% of our studied farmers had no idea on reasons for AMR, farmers in another country believed that increasing the use of complementary therapies (herbs), creating quick and accurate diagnostic tools, and educating prescribers and patients about AMs therapy could be the most crucial steps toward lowering AMU and AMR[1]. According to a study by WHO[59] that was done across several nations, the majority of respondents felt that pharmaceutical corporations should create new AMs to combat the issue of AMR. Despite the promise of developing new AMs, prudent AMU remains the most effective strategy[60,61].

One of the limitations of this study is that our results are based on information provided by farmers; thus, we were unable to verify if the AMU practices they claimed to use were carried out by them. However, we cross-checked the AM packets, prescriptions, and the left-over AMs to minimize the error in the information they provided. Farmers' responses may have also been influenced by recall bias, but we were able to reduce this prejudice by concentrating only on the current cycle of chicken production regarding AMU information. We did not investigate the farmer's attitudes on how to tackle the resistance in this study, which is suggested to conduct in further studies.

Conclusions

Our study highlights the widespread and careless use of AMs in Bangladesh's poultry industry driven by inadequate KAP and insufficient veterinary oversight. The elevated AMU rates in meat-type chickens emphasize the urgent interventions to mitigate potential risks of AR and AMR. We recommend stringent regulations on AMs, requiring prescriptions from licensed veterinarians, and enhancing farmer education on responsible antibiotic use. It is also necessary to ease access to veterinary services in a timely manner. Collaborative efforts among stakeholders are essential for enforcing evidence-based policies that promote sustainable poultry farming. Furthermore, longitudinal studies are required to evaluate the long-term effects of AMU on poultry production and assess the success of implemented interventions.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions
AI conceptualized, conceived, prepared the study design, and sampling methods of the study. MH, AKMDK, MAK, MAS, ZIN, SI, MMH, AI developed the questionnaire. MH, AKMDK, MAK, MI, MAS, ZIN, AAM, SI managed the data collection. MH, TA, AI drafted the manuscript. MH, TA, MI, AI conducted data and statistical analysis. CEFC, MMH, TS reviewed and made critical comments on the manuscript. All authors were involved in the development and revision of the manuscript, and all authors read and approved the final manuscript. All authors reviewed and approved the manuscript for publication.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The study is approved by the Ethics committee of Chattogram Veterinary and Animal Sciences University (Memo no: CVASU/Dir(R&E) EC/2020/241[5], Date:15/04/2021) and in accordance with the guidelines and regulations in the Declaration of Helsinki. Informed consent was obtained from the participants by study staff after discussing the informed consent form/study with each participant.

Additional information

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Correspondence and requests for materials should be addressed to A.I.