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Knowledge and practices related to antibiotics among poultry producers and veterinarians in two Indian states

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ABSTRACT

Background: Antibiotics are frequently utilized in livestock, particularly poultry, for therapy and growth promotion, resulting in antimicrobial resistance. Multidrug-resistant bacteria are frequent in poultry samples from India. The purpose of this study was to better understand main antibiotic consumption patterns in poultry value chains, as well as antibiotic knowledge and practices among the stakeholders.
Methods: A cross-sectional survey was conducted in Assam and Karnataka, India. The poultry farmers were interviewed on antibiotic usage, antibiotic knowledge, feeding practices, and preventive measures on the farm. Poultry farmers reported their veterinarians, and we also interviewed them on knowledge and practices related to antimicrobial use in poultry and antimicrobial resistance. Item response theory (IRT) was used to assess the association between the answers and demographic factors.
Results: This survey interviewed 62 poultry farmers and 11 veterinarians. Small poultry farms with fewer than 4000 birds were owned by 51.6% of farmers. Most poultry farmers had heard about antibiotics, and 62.9% thought they cured all diseases. If one chicken is sick, 72.6% said others should be given antibiotics to prevent the disease. All veterinarians utilized tetracyclines, aminoglycosides, and cephalexin on the poultry farms. Over half (54.5%) stated antibiotics prevent diseases, and 72.7% said they treat and prevent diseases. Some (45.5%) said antibiotics boost growth. IRT analysis showed that 8 questions assessed a knowledge scale well. Univariable analysis showed that Assam farmers and women were likely to have have more knowledge.
Conclusion: The poultry farmers were mostly unaware of the relation between antibiotic use and antimicrobial resistance. Despite being aware, the veterinarians agreed with use antibiotics as a prophylactic measure. It is vital that these stakeholders understand the repercussions of such widespread antibiotic use. In order to increase knowledge, frequent trainings and antimicrobial stewardship programmes with effective communication and incentives for behaviour change should be conducted.

1. Introduction

The poultry sector in India is expanding rapidly. While agricultural crop production has been increasing at a pace of “1.5 to 2%” per year, broiler and egg production has been increasing at a rate of “5 to 6%” per year [1]. As a result, India is currently the world’s third largest egg producer and the world’s eighth largest broiler producer [1]. High mutton prices, religious restrictions on beef and pork, and the scarcity of fish outside of coastal areas have all contributed to poultry meat becoming India’s most preferred and consumed meat [2]. The poultry industry in India has undergone a structural and operational paradigm shift. In just over four decades, India’s poultry business has grown from a

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backyard activity to a huge commercial enterprise. Significant investments have been made in breeding, hatching, rearing, and processing as part of this change [3]. Farmers in India have transitioned from rearing non-descript birds (native birds of an unregistered breed) to rearing hybrids, which grow faster, live longer, have better feed conversion, and hence generate higher profits for the rearers [4]. Many broiler enterprises have vertically integrated their operations in recent years, accounting for around 70% of total chicken meat output in the country. The integrator invests in the full value chain in this approach, while poultry farmers invest in chicken houses and equipment on their current land. Integrators give day-old chicks, feed, medicines/vaccines, process and cost management training, and technical supervision to farmers. Farmers are paid for rearing birds based on agreed-upon prices when integrators collect the broilers at roughly 42–45 days of age. Farmers receive a bonus if their feed conversion ratio (FCR) or mortality rate is better than the contracted level [2]. As a result, the farmers benefit from guaranteed profits. Also, there are no middlemen to contend with; there is only the integrator, farmer, and wholesaler in the value chain [2].

Many classes of antimicrobials like tetracyclines, aminoglycosides etc. that are used for humans are also used in food animals. Antibiotics in food animals are not limited to therapeutic use, but also used for metaphylaxis (administration to animals when perceived to be in contact with animals diagnosed with disease), for prophylaxis (administration of antimicrobials to animals to prevent disease) and as growth promoters to boost feed efficiency and increase weight gain [5,6]. Antibiotics such as colistin, tetracycline, doxycycline, and ciprofloxacin, which are critical to human health, are commonly used for growth promotion in poultry in developing countries [7–10]. Antibiotic use as growth promoters is increasing in developing countries due to the rising population and an escalated demand for animal products [11]. In India, only 30% of antibiotics used in poultry is for therapy or disease prevention and the remaining 70% is for growth promotion [12]. Estimates of global antibiotic use in food animals indicate that India accounts for 3% of global consumption and is among the top consumers worldwide, along with China, the United States, Brazil and Germany [11,13]. However, shifting patterns of wealth and dietary preferences indicate increased demand for animal protein, which is pushing antibiotic use in food animals, and as a result, antibiotic consumption in food animal production in India is expected to increase by 312% by 2030, making India the fourth-largest user of antibiotics in animals [14]. The widespread use of antibiotics has accelerated the emergence of antimicrobial resistance (AMR) in bacteria. The prevalence and number of these resistant bacteria are rising. According to a recent study, bacterial AMR contributed to around 5 million human deaths in 2019—of which roughly 1.3 million were directly related to resistance [15]. And looking at the current antibiotic use trends both in humans as well as agriculture, these figures are probably going to rise. Antibiotic use in humans or animals produces selective pressure that leads to the development of resistance in the bacteria that are exposed to these antibiotics [16]. Farm animals and humans are infected by the same species of bacteria, implying that these species are most likely exchanged at some level [15].And there is evidence that suggests that humans and animals share AMR bacteria [15,17].

A high prevalence of multidrug-resistant (MDR) and extended-spectrum beta-lactamase (ESBL) producing *Escherichia coli* in intensive chicken farming in India and the prevalence of MDR avian pathogenic *E. coli* associated virulence genes in backyard layer chickens has been described in a recent review of antimicrobial resistance in poultry farming in low resource settings [18]. A study of 12 randomly selected poultry farms in four north Indian poultry-producing states—Uttar Pradesh, Haryana, Punjab, and Rajasthan—found MDR bacteria in poultry litter, soil, and nearby agricultural land [6]. The study demonstrated high resistance to all vitally important antibiotic classes (5 "highest priority" and the rest "high priority") [6]. Multiple studies from India have similarly revealed a high prevalence of MDR bacteria in poultry samples [9,19,20].

Most animal studies done in India examined the resistance profiles of bacteria isolated from livestock, poultry, and aquaculture; however, the frequency of antibiotic use and reasons for use during animal and poultry rearing are poorly documented in the published literature. Very little research has been done in India on knowledge, practices, and perceptions of the poultry farmers and veterinarians working in the poultry sector related to antibiotics and anti-microbial resistance. In order to curb the imprudent usage of antibiotics in the poultry farms of India, first it is important to understand the awareness levels, practices, and perceptions of these stakeholders. Therefore, this study was conducted to understand the consumption patterns of key antibiotics in the poultry value chains and study knowledge and practices pertaining to antibiotics in poultry value chains.

2. Methods and materials

2.1. Study design and study areas

A cross-sectional survey in collaboration with Food Safety and Standards Authority of India (FSSAI) was conducted from September 2019–March 2021 in purposively selected villages of two Indian states; Assam (Sonapur, Mirza, Rampur, Chaygaon, Morigaon) and Karnataka (Sullia, Sidlaghatta, Hoskote, Nelamangla) (Fig. 1). Karnataka is a southern region of India with a very well-developed poultry system with integrated poultry companies owning most of the farms and Assam is a northeastern state with a mix of both backyard poultry farms and integrated farms. Both these states are among the Indian states with the highest poultry inventory but Assam has a slightly lower poultry population (sixth and seventh states in terms of poultry numbers respectively) [21]. A list of all the poultry farms in the study villages was made with the help of the local partners (Assam agricultural University (AAU) and National Institute of Veterinary Epidemiology and Disease Informatics (NIVEDI), Bangalore) and the poultry farms were randomly selected from the list. The poultry farms covered in the study regions

Fig. 1. Indian map highlighting the study states where the study was conducted.

were broiler farms. The farms were divided into three categories- small (<4000 birds/farm), medium (4000–8000 birds/farm) and large (>8000 birds/farm). Thirty poultry farms were visited in Assam and 32 in Karnataka.

2.2. Ethical approval

On October 16, 2019, ethical approval was obtained from the Institutional Animal Care and Use Committee (IACUC) of the International Livestock Research Institute (ILRI) under the reference number ILRI-IACUC2019–33. Additionally, the collaborating institutes, namely the Food Safety and Standards Authority of India (FSSAI) and the ICAR-National Institute of Veterinary Epidemiology and Disease Informatics, also granted their approval. An informed consent was taken from the participants and only the participants who gave their written consent were interviewed.

2.3. Data collection

The poultry farmers/owners were informed about the project, and those who gave consent were interviewed with a pretested structured questionnaire to determine their knowledge, attitudes, and self-reported practices regarding antimicrobial use (AMU). The questionnaire was developed by experts with substantial experience in food safety and antibiotic resistance. The questionnaire was pilot tested in one of the study sites i.e., Assam interviewing a few poultry farmers from a different area than the selected study region. A debriefing session was done by the project team with the field investigators and minor changes were made. The questionnaire was divided into several sections, the most important of which included questions on sociodemographic factors, antibiotic usage, antibiotic knowledge, and attitude, feeding practices, and preventive measures. Interviewers asked the questions in the local language, and the responses were entered in English at the time of the interview. Also, an observation checklist for the interviewer was used to note characteristics like type of litter used, cleanliness on the farm, cleanliness of the birds, any discarded packets of medicines/antibiotics etc.

By interviewing the poultry farmers, the consulting veterinarians were identified and approached for an interview. Those who gave consent were interviewed using a pretested questionnaire, to check their knowledge and practices related to antimicrobial use in poultry and antimicrobial resistance. The questionnaire included questions on knowledge and practices related to antibiotic use, antimicrobial resistance, attitude on antibiotics and prevention measures they take on the poultry farms. Unfortunately, due to the COVID-19 pandemic, it was not possible to interview as many from Karnataka as Assam.

2.4. Data analysis

Data was entered in Microsoft Excel and analysed using STATA 14.0 (STATA Corp Ltd., College Station, TX, USA). Firstly, descriptive analysis was carried out for all the poultry farmers as well as veterinarians. Categorical variables were expressed as frequencies and percentages. The test of associations was done using the Pearson chi-square test and, where applicable, Fisher's exact value. A p-value <0.05 was considered significant.

Eleven items were used to assess farmer's knowledge related to antibiotics and antimicrobial resistance. The knowledge results were originally categorized as multiple choice or "yes vs. no," and all of them were then reclassified as "correct" vs. "incorrect." Data were coded by giving 1 to correct and 0 to the incorrect response to a given question or item. A total knowledge score was calculated for each poultry farmer.

Cronbach's alpha, a parameter, expressed as a number between 0 and 1, that measures how well all the knowledge items on a test measure the same concept, was used to check the internal consistency of the test [22,23]. Item response theory (IRT) analysis, which offers details on each item's discrimination and difficulty across various levels of the underlying trait, was used. IRT is based on the assumption that there is a single unmeasured (latent) feature that underlies all of the items (unidimensionality). By examining the eigenvalues and factor loadings from an exploratory factor analysis, the assumption of unidimensionality was checked. A two-parameter logistic (2PL) model was used for knowledge items to calculate the probability that a person with a given level of knowledge would agree or disagree with a specific item. This model is represented by the equation: $P_{ij}\ (u_i = 1 | \Theta = t) = 1/1 + \exp\ [-1.7\ a_i\ t - b_i]$ [24]. Here a_i is the discrimination parameter for item i (i = 1, …, n), b_i is the difficulty parameter for item i, u_i is the response of the person with trait level θ to item i, and 1.7 is a scaling constant.

The discrimination parameter varies between items and therefore, the Item Characteristic Curve (ICC) of the different items can intersect and have different slopes. The steeper the slope, the better the discrimination of the item, as it will be able to detect slight differences in the knowledge level of the respondents. The difficulty parameter reflects how difficult it was for an individual to answer the knowledge question (a high difficulty parameter would indicate that relatively few individuals were able to give the correct answer). A single composite trait (latent variable) called theta (θ) was used for description or analysis of the ability of person. Predicted values of theta were computed for each respondent based on their aggregate response to the knowledge questions. Linear regression was done to see the association of the predicted theta values with farm type, state, and gender of the respondents.

3. Results

3.1. Participant demographics- poultry farmers

Out of the 62 poultry farmers who were interviewed, 48.4% were from Assam and 51.6% were from Karnataka. Most of these farmers were men (83.9%) and many had a secondary level education from class 5–10 (45.2%). Some farmers were between 31 and 40 years (37.1%), while 30.6% were between 20 and 30 years, and there were few participants from the oldest categories (Table 1).

All the poultry farms covered in the survey were broiler farms with an integrated system and in contract with a poultry company. Half (51.6%) of the farmers had a small-scale poultry farm with <4000 birds per farm. The majority (88.7%) of poultry farmers owned their own farm. Deep litter system was used by more than half (53.2%) while the remaining 46.8% used cage system. When a new batch of birds arrives on their farm, many of the farmers (90.3%) said they did not practice quarantine, and nearly all of them (98.4%) said they used veterinary medications. Many farmers (90.3%) reported using poultry waste as manure. Table 1 gives more description on the characteristics of poultry farmers and the farms.

3.2. Knowledge and practices of poultry farmers related to antibiotics

Small-scale farmers were more likely to agree with the statement that "antibiotics are used to treat or cure diseases" as compared to medium and large-scale farmers (65.6%, 14.3% and 8.7% respectively; $p < 0.01$). Only a small percentage of them (19.4%) disagreed that all diseases need treatment, with large-scale farmers more likely to disagree as compared to medium and small-scale farmers (39.1%, 28.6%, 3.1% respectively; $p < 0.01$). Many of them (69.4%) disagreed with the statement that they would use more medicine if they could afford it with small-scale farmers more likely to disagree as compared to medium and large-scale farmers (90.6%, 42.9%, 47.8% respectively; $p < 0.01$). Many (62.9%) believed that antibiotics stop all diseases, and only about a third (29.0%) agreed that administering antibiotics too frequently would render them ineffective. Most (72.6%) thought that if one chicken is sick, then others should be treated with antibiotics to prevent the disease and the large-scale farmers were more likely to disagree with this statement as compared to small and medium-scale farmers (47.8%,

Table 1
Demographic, socioeconomic information of the poultry farmers and farm characteristics.

Variables	Categories	n (%)
State	Assam	30 (48.39%)
	Karnataka	32 (51.61%)
Gender	Male	52 (83.87%)
	Female	10 (16.13%)
Education	No education	4 (6.45%)
	Primary	5 (8.06%)
	Class 5–10	28 (45.16%)
	Higher secondary	15 (24.19%)
	Graduation and above	10 (16.13%)
Age of the farmers (years)	20–30	19 (30.65%)
	31–40	23 (37.10%)
	41–50	12 (19.35%)
	51–60	5 (8.06%)
	Above 60	3 (4.84%)
Farm characteristics		
Farm size	Small (<4000 birds/farm)	32 (51.61%)
	Medium (4000–8000 birds/farm)	7 (11.29%)
	Large (>8000 birds/farm)	23 (37.10%)
Role in the farm	Owner	55 (88.71%)
	Worker	7 (11.29%)
Rearing system	Cage system	29 (46.77%)
	Deep litter system	33 (53.23%)
Practice quarantine when new batch of birds arrive on the farm	Yes	6 (9.68%)
	No	56 (90.32%)
Use veterinary drugs on the farm	Yes	61 (98.39%)
	No	1 (1.61%)
Dispose poultry waste	Use as manure	56 (90.32%)
	Throw away near the farm	1 (1.61%)
	Sell it	5 (8.06%)

6.3%, 57.1% respectively; $p < 0.01$). Table 2 shows the distribution of various knowledge and practices related to antibiotics among the small, medium, and large-scale poultry farmers.

3.3. Assessment of the knowledge measurement scale- IRT analysis results

When optimized for Cronbach's alpha score, 8 variables out of eleven showed acceptable consistency, 0.71. Based on factor analysis of this scale with eight items, the assumption of unidimensionality seemed to be met as the eigenvalue ratio between factor 1 and factor 2 was >5. The discrimination and difficulty parameters from the IRT analysis are presented in Table 3. The discrimination in the 2PL ranges from 0.97 to 1.26 suggesting all the questions in the IRT model showed an acceptable discrimination and a good level of difficulty. The item with score_9, which is a disagreement on the statement "Increasing the amount of antibiotic makes it more effective", had the highest discrimination ($a_i = 1.89$), whereas the item with score_2A, which is a question on "why antibiotics are given", had the lowest discrimination ($a_i = 0.97$)

Table 2
Knowledge, attitude and practices related to antibiotics.

Item	Total (*N* = 62)	Small (*N* = 32)	Medium (*N* = 7)	Large (*N* = 23)	P-value
Have you heard about antibiotics? (Yes)	44 (70.97%)	25 (78.13%)	6 (85.71%)	13 (56.52%)	0.145
Agree with the statement: *"Antibiotics are used to treat or cure diseases"*	24 (38.71%)	21 (65.63%)	1 (14.29%)	2 (8.70%)	0.000
Disagree* with the statement: *"Feed must have medicine in it"*	16 (25.81%)	10 (31.25%)	1 (14.29%)	5 (21.74%)	0.555
Disagree* with the statement: *"More the antibiotic costs the better it is"*	37 (59.68%)	21 (65.63%)	5 (71.43%)	11 (47.83%)	0.330
Disagree* with the statement: *"All medicines used in humans can be used in animals"*	34 (54.84%)	16 (50%)	4 (57.14%)	14 (60.87%)	0.721
Disagree* with the statement: *"I prefer to buy feed having an antibiotic"*	28 (45.16%)	14 (43.75%)	4 (57.14%)	10 (43.48%)	0.795
Disagree* with the statement: *"The pharmacist is as good as veterinarian to give an antibiotic"*	15 (24.19%)	5 (15.63%)	1 (14.29%)	9 (39.13%)	0.108
Disagree* with the statement" *"All diseases need treatment"*	12 (19.35%)	1 (3.13%)	2 (28.57%)	9 (39.13%)	0.003
Disagree* with the statement: *"I would use more medicine if I could afford it"*	43 (69.35%)	29 (90.63%)	3 (42.86%)	11 (47.83%)	0.001
Agree with the statement: *"There are many poor-quality antibiotics in the market"*	28 (45.16%)	14 (43.75%)	4 (57.14%)	10 (43.48%)	0.795
Disagree* with the statement: *"Increasing the amount of antibiotic makes it more effective"*	32 (51.61%)	15 (46.88%)	4 (57.14%)	13 (56.52%)	0.743
Disagree* with the statement: *"Antibiotics stop all diseases"*	23 (37.10%)	15 (46.88%)	1 (14.29%)	7 (30.43%)	0.191
Agree with the statement:	18 (29.03%)	12 (37.50%)	2 (28.57%)	4 (17.39%)	0.269

(continued on next page)

Table 2 (*continued*)

Item	Total (*N* = 62)	Small (*N* = 32)	Medium (*N* = 7)	Large (*N* = 23)	P-value
"Using antibiotic too often makes it ineffective"					
Disagree* with the statement:	17 (27.42%)	2 (6.25%)	4 (57.14%)	11 (47.83%)	0.001
"If one chicken is sick, then others should be treated also to prevent disease"					

Table 3
discrimination and difficulty values of the items in the knowledge scale containing variables showing consistency.

Item	Discrimination (a_i) and difficulty (b_i)	Coef.	Std. error	95% confidence interval
Score_2A_Why antibiotics are given?	a_i b_i	0.97 1.98	0.56 0.92	−0.12 2.08 0.16 3.80
Score_1_disagree with "feed must have antibiotic in it"	a_i b_i	1.76 0.90	0.75 0.30	0.29 3.24 0.30 1.50
Score_2_disagree with "More the antibiotic costs, the better it is"	a_i b_i	1.66 −0.34	0.73 0.24	0.22 3.09 −0.82 0.12
Score_3_disagree with "All medicines used in humans can be used in animals"	a_i b_i	1.00 −0.23	0.44 0.31	0.12 1.88 −0.85 0.38
Score_5_disagree with "The pharmacist is as good as vet to give an antibiotic"	a_i b_i	1.70 0.99	0.74 0.32	0.25 3.16 0.34 1.63
Score_9_disagree with "Increasing the amount of antibiotic makes it more effective"	a_i b_i	1.89 −0.05	0.84 0.21	0.24 3.55 −0.47 0.36
Score_10_disagree with "Antibiotics stop all diseases"	a_i b_i	1.23 0.55	0.52 0.31	0.21 2.26 −0.05 1.16
Score_12_agree with "Using antibiotic too often makes it ineffective"	a_i b_i	1.26 0.92	0.53 0.37	0.20 0.31 0.18 1.65

suggesting that it contributed less to the scale. The difficulty parameter was the lowest for the item with score_2 ($b_i = -0.34$), which is a disagreement with the statement "more the antibiotic costs, the better it is. On this basis, we could make an eight-item, unidimensional scale (Fig. 2).

A single composite trait or variable called theta (θ) was used to characterize the knowledge level related to antibiotics. Theta gives an overall estimate of the quality being measured and takes into account the difficulty and discrimination values for each item and hence is a more reliable overall measure than a simple sum of the individual items in the scale. For each respondent, a theta (θ) score was computed. The theta value representing the range of the knowledge level of the farmers varied between −1.2 to 1.6. The test information function in Fig. 3 shows that the knowledge scale with eight items does a decent job of separating respondents with an above average knowledge level from the ones with below average knowledge level.

In the univariable analysis, theta was significantly associated with state and gender i.e., the poultry farmers from Assam ($p = 0.00$) and the female poultry farmers ($p = 0.03$) were likely to have a higher theta score. However, in the multivariable analysis, no significant association of theta was found with state ($p = 0.07$), gender ($p = 0.06$), or type of poultry farm ($p = 0.79$).

3.4. Veterinarians - demographics, antibiotic use, and knowledge

In total, 11 veterinarians working specifically with poultry farms were interviewed. Out of these, 10 (91%) were from Assam. Nine out of eleven of these veterinarians were males and only 2 were females. Many (8, 72.7%) fell in the age group of 20–30 years, some (2, 18.2%) were from 31 to 40 years and only one of them was above 40 years. Almost all (9, 81.8%) had 1–5 years of working experience.

Although they were all aware of antibiotics, some (3, 27.3%) could not correctly explain an antibiotic, stating that antibiotics are used to kill all microorganisms, or prevent diseases. Over half of them (6, 54.5%) agreed that antibiotics are given to prevent diseases and 8 (72.7%) said that antibiotics are given both to treat and prevent diseases. Five of them also said that antibiotics are given to promote growth. Fig. 4 shows commonly used antibiotics by the veterinarians on the poultry farms.

Five veterinarians (45.5%) sourced the antibiotics from the government while the rest (54.5%) sourced them from the local pharmacy. All of them agreed that they knew about withdrawal period and 8 (72.7%) defined withdrawal period correctly. All of them said that they always informed the farmers to follow a withdrawal period when the birds are given antibiotics.

The majority of veterinarians (9, 81.8%) disagreed with the statement that feed must contain medicine in it to prevent sickness in birds. Only a few (2, 18.2%) thought all medicines that are used in humans can also be used in animals. None of them suggested purchasing feed that contains antibiotics. More than half (6, 54.5%) agreed that all diseases require treatment. Around half (5, 45.5%) were in agreement that if farmers could afford it, they would use more medication. Most (8, 72.7%) stated that if one chicken is sick on the farm, the whole flock should be given antibiotics to prevent the disease.

All of them had heard about antimicrobial resistance and eight of them agreed that if antibiotic is used too often it becomes ineffective. Only 4 (36.4%) could define antimicrobial resistance correctly and just 3 (27.3%) had received training on rational use of antibiotics. Most (9, 81.8%) said that AMR is a big threat to human health in the future.

4. Discussion

In our study most poultry farms were broiler farms that functioned under the integrated poultry system, with a contract from a poultry company that guaranteed farmers a consistent income without the involvement of a middleman. This is in alignment with other studies that reveal that the poultry industry has shifted from a backyard activity into a major commercial activity in just four decades [25,26]. Most of the poultry farms used the deep litter system, which is convenient, affordable, and allows an easy upkeep of the birds. Commercial broiler farms in south Asian regions are mostly reared in a deep litter system and a substantial proportion also uses cages which is considered unacceptable for welfare reasons in many countries [27]. Multiple studies however, have reported a high adoption of deep litter system in India [28].

The majority of farmers used chicken faeces as manure, but localized manure disposal can cause public health issues [29]. The main danger posed by chicken faeces is its contamination with pathogens, such as bacteria, viruses, parasites, and antibiotics, which can be harmful to humans, animals, and the environment [30].

The farmers' understanding of antibiotics, their use, and antimicrobial resistance was limited. Even though most farmers had heard of antibiotics, only a small percentage of them thought that they were used to treat diseases. Many of them thought that a pharmacist could administer an antibiotic just as well as a veterinarian could. Few people were aware that using an antibiotic frequently can render it ineffective. Other Indian studies that discuss the lack of awareness and understanding regarding antibiotics among livestock and poultry producers similarly found low levels of knowledge and wrongful perceptions

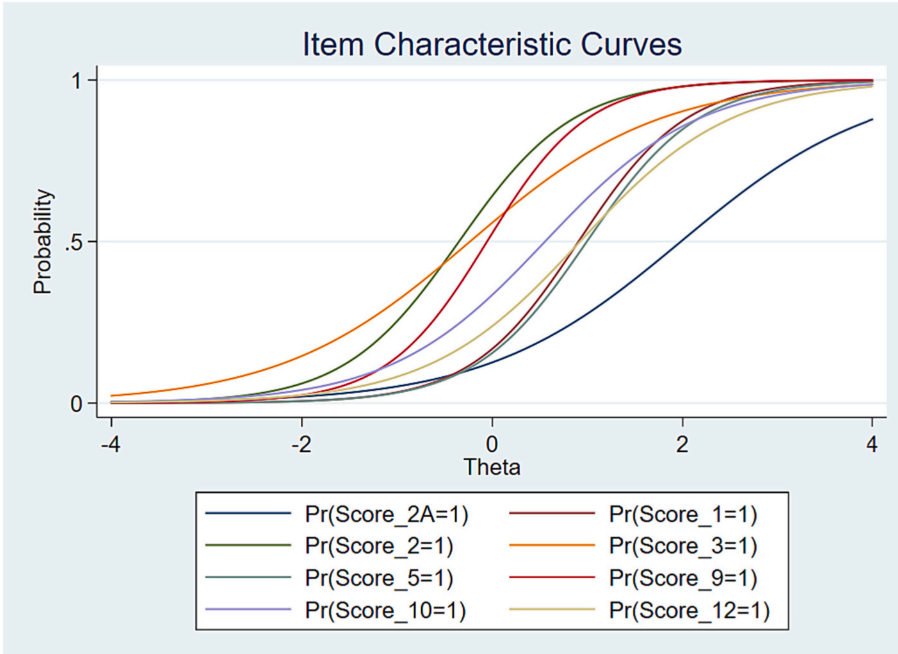

Fig. 2. Item characteristic curve for the eight knowledge scale items on antibiotics.

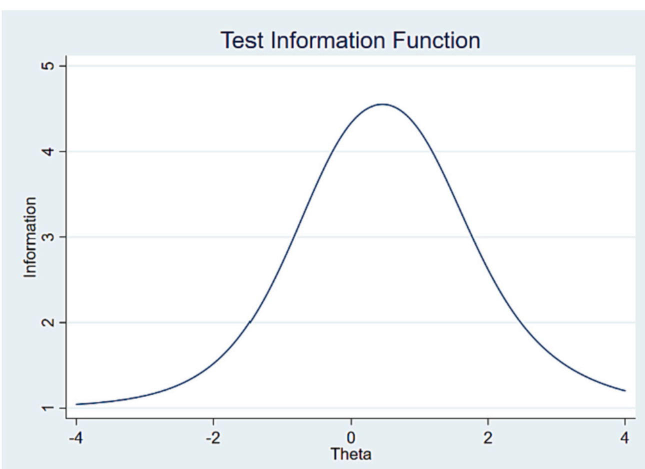

Fig. 3. Test information curve for the knowledge scale related to antibiotics.

[31,32]. Many of the farmers in our study agreed that medicines must be included in the feed and if one chicken is sick, the whole flock must be given an antibiotic to prevent the disease. Similar findings were found in other research conducted in India, where it was shown that poultry farms typically utilize antibiotics for preventative purposes [31] and that poultry feed does contain antibiotic growth promoters [32]. According to the study findings, the majority of these poultry farms operated under an integrated system, in which farmers are paid for rearing the broilers at agreed-upon prices. Farmers earn a bonus if their feed conversion ratio (FCR), which measures weight gain or mortality rate, exceeds the contracted amount. As a result, the farmers receive assured profits. Antibiotics are known to promote chicken health and cause weight gain. Despite the cost, their removal will have an impact on chicken output, resulting in lower financial gains for these producers. Antibiotics may improve chicken performance, but their excessive usage as growth promoters is harmful to human health. However, discontinuing antibiotics has an economic impact. Some academics suggest that using antibiotics to improve animal performance through greater growth and feed efficiency lowers the cost of meat and eggs; in other words, prohibiting antibiotics will raise the cost of animal products [33]. It is a daunting task that must be approached with caution to ensure both food safety as well as optimal performance. Researchers are seeking for alternatives to antibiotics in poultry farming, such as natural sources of herbs and medicinal plants. Antibiotic alternatives include probiotics, prebiotics, enzymes, etc. Prebiotics are potential alternatives to antibiotics used for growth promotion [33].

These results also demonstrate the lack of awareness among the poultry farmers when it comes to the use of antibiotics. When the awareness is low there is a higher likelihood of improper dosing, incorrect administration, and the use of antibiotics without veterinary oversight, all of which can accelerate the development of antimicrobial resistance. Antibiotic residues are a major concern for consumers because they can cause allergic reactions and other negative health effects, and they can also contribute to the growth of bacteria that are resistant to antibiotics in the human gut microbiota. Improper use of antibiotics in poultry farming can also lead to the release of antibiotic residues into the environment through waste and runoff. This can contribute to contamination of water sources and soil, potentially leading to the development of environmental reservoirs of antibiotic resistant bacteria.

Using IRT techniques, researchers may create better measuring scales and assess the value of individual items in the survey tool [34]. In this study the 2PL logistic model fitted the knowledge variables quite well. Eight knowledge variables showed an acceptable consistency and were further tested for discrimination and difficulty levels. We found that the discrimination parameters for them were acceptable, but not great. The difficulty parameters, however, were all greater than −0.34 which means there were no questions too easy for the target group. This reflects a generally low knowledge among the respondents. The test information function curve further depicted that this subset of knowledge questions was valid and could separate the individuals with above average knowledge level from the ones with below average knowledge level to a good extent. As a result of these findings, future studies should concentrate on evaluating more thorough knowledge measurement scales towards antibiotic use and AMR but can use the eight items in this study as a basis. The coverage of the information that the survey tool is meant to measure should be the main focus. Also, more items with high

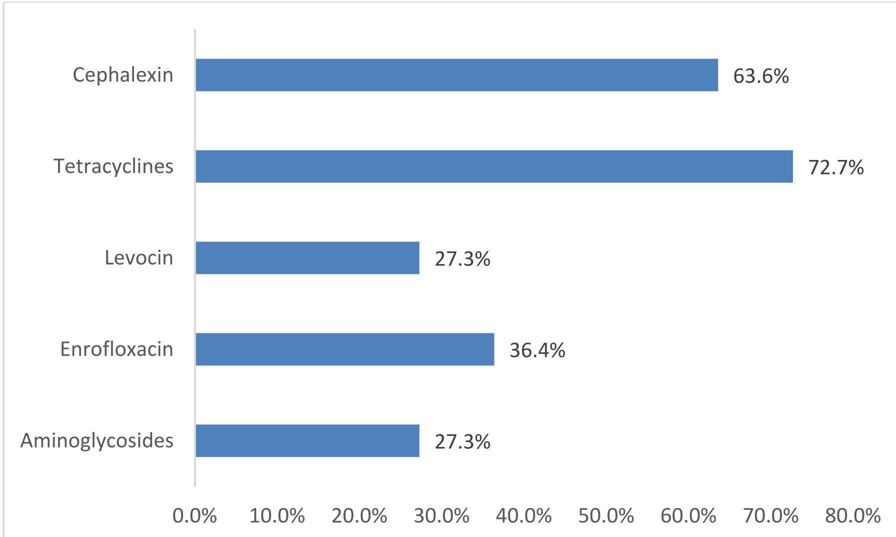

Fig. 4. Common antibiotics prescribed/used by the veterinarians on the poultry farms.

discrimination must be added in the tool. It did seem that female respondents had better knowledge, but future larger studies can better identify explanatory factors.

Most of the surveyed veterinarians were men with 1–5 years of experience working in the poultry farms. Unfortunately, due to the COVID-19 pandemic, it was not possible to interview as many from Karnataka as Assam. The veterinarians in the survey were quite familiar with antibiotics and antimicrobial resistance. They endorsed the use antibiotics not just for treatment but for preventive purposes as well. Similar results have been reported in studies done in other developing countries where the veterinarians are aware of antibiotics, concepts of antimicrobial resistance but do use antibiotics as prophylactic measures [35,36]. This practice is beneficial from the perspective of the farmer but has negative impacts on public health. The veterinarians sourced antibiotics from both government supply and local pharmacy. The most common antibiotics prescribed and used by them on these poultry farms were tetracyclines and cephalosporins. There are other studies from India that reveal the use of these critically important antibiotics in the broiler farms [31,37]. Very few of the surveyed veterinarians had received training on rational use of antibiotics. Similar studies from India also report lack of trainings for the veterinarians and suggest upon strengthening the veterinary human resources as they can adequately address the issue of antimicrobial resistance [38,39]. There is a conflict of interest that veterinarians face in both doing what is best for their client and promoting public health. Creating incentives for veterinarians and farmers to adopt alternative disease prevention and control measures, such as vaccination programs, can help reduce reliance on antibiotics. But most importantly, this also requires a multi-stakeholder approach involving veterinarians, farmers, regulators, and public health authorities to promote responsible antibiotic use in poultry farming while safeguarding animal health and public health. However, the sample of the farmers and veterinarians interviewed in this study are not representative of the no. of these stakeholders in the area and therefore, the results of this study can not be generalized.

5. Conclusion

Finally, based on the findings of this research, there is a dearth of knowledge about antibiotics and AMR among poultry producers, and antibiotics are used as preventative measures by both the farmers and the veterinarians. The veterinarians are well-informed, but there is clearly a training deficit. It is crucial that these stakeholders are made aware of the effects of taking antibiotics so liberally because India's poultry sector is one of the country's fastest-growing markets for food animals. Our findings demonstrate the necessity of (1) promoting antibiotic knowledge and awareness among chicken farmers, and (2) setting up regular trainings on responsible antibiotic use for all stakeholders, including poultry feed suppliers. However, this study also illustrates the conflict of interest which occurs because what is best for the farmer (using antibiotics preventively and for growth promotion) and hence best for the veterinarian for whom the famer is a client, is not best for society at large. Given this conflict of interest just providing knowledge and training may not be sufficient to change behaviour. The current imperative is to adopt a "One Health" strategy that enables the implementation of behavioural change interventions among farmers, veterinarians, and other stakeholders. This approach involves the collaboration of all stakeholders and the promotion of prudent antimicrobial usage and responsible antimicrobial stewardship. To stop the spread of AMR in the poultry and livestock value chains, we need to find integrated approaches that are based on good One Health principles, as well as economic evidence, equity, and everyone having access to good healthcare for themselves and their animals.

CRediT authorship contribution statement

Garima Sharma: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tushar Kumar Dey:** Writing – review & editing, Project administration, Investigation. **Razibuddin Ahmed Hazarika:** Writing – review & editing, Project administration. **Bibek Ranjan Shome:** Writing – review & editing, Project administration. **Rajeshwari Shome:** Writing – review & editing, Project administration. **Vijay Pal Singh:** Writing – review & editing, Project administration, Conceptualization. **Ram Pratim Deka:** Writing – review & editing, Project administration, Methodology, Data curation, Conceptualization. **Delia Grace:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Funding acquisition, Conceptualization. **Johanna F. Lindahl:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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