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Factors Associated with Occurrence of Antibiotic Resistance in Broiler Chickens in Selected Districts, Zambia

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ABSTRACT

A cross-sectional study was conducted in five districts of Zambia. The study aimed to investigate the risk factors associated with AntiMicrobial Resistance (AMR) in broiler chickens in Zambia. A total of 109 broiler farms were included in the study, of which 104 were small-scale farms, 2 were medium-scale, and 3 were commercial-scale. A semi-structured questionnaire was administered alongside the collection of cloacal swabs and litter samples to determine the risk factors associated with the occurrence of AMR of food pathogen microorganisms on the selected broiler farms. Data collected was analysed using STATA version 12. The broiler farm-level AMR prevalence was 84.4 per cent (n= 109). Gender, marital status, administration of drugs by veterinary personnel or the farmer and the poultry house drainage destination were among the predictors of AMR on broiler chicken farms. The high prevalence of AMR in broiler chicken farms suggests a high dependence on antimicrobials in poultry production in Zambia. In addition, socio-demographics such as gender and age, as well as farm characteristics and management practices, may primarily contribute to the high prevalence of antibiotic resistance. This study has demonstrated the association between the AMR of foodborne pathogens and the risk factors for AMR during poultry production. Therefore, it is necessary for risk management measures such as biosecurity to be put in place to target the identified AMR predictor variables. There is also a need to strengthen AMR surveillance to ensure intervention strategies are appropriate to the existing risk.

Keywords: *Antimicrobial resistance, Prevalence, Broiler chickens, Zambia*

Introduction

Antimicrobial agents are beneficial to human health, animal well-being and food production, through their contribution to reducing morbidity and mortality caused by pathogenic microorganisms in both humans and animals (Gardner *et al.*, 2012; Kasimanickam *et al.*, 2021). Currently, there are limited alternatives to antimicrobial agents in treating infectious diseases. However, their misuse in agriculture, veterinary and human medicine (Sindato *et al.*, 2020) can contribute to developing antimicrobial resistance (AMR) (Gardner *et al.*, 2012; Kasimanickam *et al.*, 2021). AMR has remained one of the growing public health problems globally World Health Organisation (WHO, 2023). AMR gained worldwide recognition as the emergence of Multi Drug-Resistant (MDR) organisms has led to increased morbidity, mortality, and economic burden (Tanwar *et al.*, 2014; WHO, 2014). AMR is accelerated by the misuse and abuse of antimicrobials in agriculture, veterinary, and human medicine (Sindato *et al.*, 2020; Kasimanickam *et al.*, 2021).

DOI: 10.53974/unza.jabs.8.1.1279

Modern food and animal production systems often include these antimicrobial agents to prevent, control, and treat bacterial infections, and these agents are also commonly used as growth promoters (Gardner *et al.*, 2012; Kapena *et al.*, 2020). Consequently, antimicrobials are found in meat as residues, and bacteria are continuously exposed to them, increasing the risk of bacterial AMR acquisition (Phiri *et al.*, 2020).

In addition, routine use of antimicrobials on farms selects for and maintains a reservoir of resistant microorganisms capable of causing human diseases or passing mobile resistance determinants to human pathogens (Davis *et al.*, 2018). The resistant microorganisms can be transmitted to humans through the environment, food products, and direct contact with food animals (Boecket *et al.*, 2015; Klous *et al.*, 2016; Spellberg *et al.*, 2016).

There is a well-documented connection between the rise in AMR infections and chicken meat production (Angulo *et al.*, 2004). Foodborne and zoonotic diseases are also linked with poultry (Hafez and Attia, 2020). According to Food and Agriculture Organisation (FAO) estimates, the total poultry meat production in the world in 2020 increased by 2.6 per cent representing 137 million tons (FAO, 2020). In 2011, the poultry meat production for Zambia was estimated at 72, 000 tonnes (Mwansa, 2013). Poultry is currently the main meat consumed by the Zambian population, contributing about 50 per cent of the total meat consumption in the country (Mtonga *et al.*, 2020; Muonga, 2020).

Studies in Zambia on broiler chickens have reported AMR strains of microorganisms to some of the WHO-classified essential antibiotics (Mtonga *et al.*, 2020; Phiri *et al.*, 2020; Muonga, 2020).

The development of AMR bacteria markedly reduces the number of antimicrobials available to effectively treat infectious diseases in humans and animals (Chiyangi *et al.*, 2017). In Zambia, MultiDrug Resistant (MDR) pathogens to the first, second, and third line antimicrobial agents have been detected in humans, leaving limited options for antimicrobial therapy for infectious diseases (Kapona, 2019). The burden of AMR is rapidly growing across antibiotic classes and has remained a significant challenge in poultry production in Zambia (Phiri *et al.*, 2020; Kamweli *et al.*, 2019).

Factors influencing AMR on poultry farms are numerous and depend on flock health status, farm characteristics and management practices, the environment, and social demographics (Guo *et al.*, 2021). There has been an increase in unregulated drugstores that stock human and antimicrobial livestock products. This has led to increased access to antimicrobial agents for use in poultry production (Chishimba *et al.*, 2016; Kamweli *et al.*, 2019). Additionally, antimicrobial agents can be purchased in markets, agro-veterinary shops, and chemists or pharmacies without prescription or involvement of a veterinarian or pharmacist (Mudenda *et al.*, 2022). To address AMR challenges, it is first necessary to identify the factors that influence the resistance of pathogens to antimicrobials. Therefore, this study identified the factors that influence AMR in broiler chicken farms in Zambia to provide baseline data that can be used as part of an integrated AMR surveillance system and the application of interventions to control AMR.

Methodology

Study design, site, and population

A cross-sectional study was conducted in five districts of Zambia, namely; Kafue, Chilanga, Ndola, Choma, and Kitwe, between December 2017 and December 2018. The districts were selected because of their increased number of broiler farmers (Ministry of Fisheries and Livestock, 2019; Harrison, Moono & Odubote, 2024), the high demand for broiler chickens attributed to the increase in the human population, and because broiler chickens are a cheap and available source of high-quality protein. The study included broiler farmers with 50 birds and above intended for selling.

Sample size and sampling technique

The sample size was calculated using AusvetEpitool (https://epitools.ausvet.com.au/oneproportion) with the following assumptions: An estimated number of broiler farms in the three provinces (Copperbelt, Lusaka and Southern Province) was 400; the confidence level was set at 95 per cent; the acceptable magnitude of error at 5 per cent; the prevalence of AMR on farms at 50 per cent. Based on the above assumptions, the estimated number of farms that was included in the study was 218. There were no records of broiler farmers in all the districts visited, making it challenging to construct the sampling frame. Therefore, broiler farmers were identified and located using the snowball sampling technique. Farmers in production were initially identified with the help of local veterinary assistants or livestock officers. Such farmers would then lead to other farmers in the season of production. Due to the challenges encountered in locating them, only 109 farmers consented to participate in the study.

The broiler farmers were categorised into three groups; commercial (>1000 birds per poultry house), medium (500 to 1000 birds per poultry house), and small-scale (<500 birds per poultry house) farmers.

Data Collection

Litter and cloacal swabs samples were collected and analysed, as reported by Phiri *et al.*, (2020). A pre-tested semi-structured questionnaire was administered to farm owners or farm workers in charge of broiler production to collect information on socio-demographic characteristics, poultry farm characteristics, and management practices as potential risk factors for AMR.

This article focused on questionnaire data analysis as part of a broader study. The AMR prevalence data and sampling points were used to determine the selection of questionnaires used to analyse AMR's risk factors (Phiri *et al.*, 2020). Only questionnaires linked to samples with results of antimicrobial susceptibility testing (AST) were entered in Excel® and imported to Stata® version 12 for analysis.

Based on Phiri *et al.* (2020), a farm was classified as having an AMR problem if at least one of the isolated target bacteria (*E. coli* or *Salmonella*) was resistant to at least 3 antibiotics from different classes (positive AMR status = 1, negative AMR status = 0).

Data Analysis

Data was analysed using STATA® 12 statistical software. The dependent variable was poultry farm AMR status, defined as the resistance of at least one isolate to at least three or more classes of antibiotics observed on the farm. The independent variables were social demographic characteristics, farm characteristics and management practices. The Chi-square test was used to evaluate associations between two categorical variables in univariate analysis. Variables with $P < 0.25$ were taken in the multivariable logistic regression model to assess the multiple effects of risk factors on the outcome using a p-value of <0.05 of the likelihood ratio test as inclusion criteria. The model was assessed for fitness using the Hosmer Lemeshow test and *lroc* procedures in Stata for the logistic model.

Ethical Considerations

Permission to conduct the study was sought from the district authorities. An informed consent statement was obtained from all study participants. Ethics clearance was sought from the University of Zambia Biomedical Research Ethics Committee (UNZA BREC (REF. 2072-2021)) Ethics Committee.

Results

Farm Level AMR Prevalence

A total of 109 broiler farms were included in this study. Table 1 shows the AMR prevalence by the district. Ndola, Choma and Kafue had higher farm AMR prevalence of 87.1 per cent, 88.9 per cent and 86.4 per cent, respectively, while Chilanga and Kitwe had an AMR prevalence of 78.6 per cent and 73.3 per cent, respectively.

Table 1: Broiler poultry farm level AMR Prevalence (n=109)

Province	District	Negative n (%)	Positive n (%)
Lusaka	Kafue	3 (13.64)	19 (86.36)
	Chilanga	3 (21.43)	11 (78.57)
Southern	Choma	3 (11.11)	24 (88.89)
Copperbelt	Kitwe	4 (26.67)	11 (73.33)
	Ndola	4 (12.90)	27 (87.10)
	Overall prevalence	17 (18.48)	92 (84.40)

Demographic characteristics, broiler poultry farm characteristics and farm management practices of the farmers

The majority (95.4%) of broiler farmers were small-scale and married (58.7%); 56 per cent were females, and 44 per cent were males (Table 2). Regarding education levels, 57.94 per cent of the farmers had attained senior secondary school and above (Table 2).

Table 2: Univariate analysis of the demographic factors for AMR on broiler poultry farms (n=109)

Variable	Level	N (%)	Positive n (%)	Negative n (%)	p-value
District	Kafue	22 (20.18)	19 (86.36)	3 (13.4)	0.662
	Chilanga	14 (12.84)	11 (78.57)	3 (21.43)	
	Choma	27 (24.77)	24 (88.89)	3 (11.11)	
	Kitwe	15 (13.76)	11 (73.33)	4 (26.67)	
	Ndola	31 (28.44)	27 (87.10	4 (12.90)	
Farm category	Small scale	104 (95.41)	88 (84.62)	16 (15.38)	0.58
	Medium scale	2 (1.83)	2 (100)	0 (0)	
	Commercial	3 (2.75)	2 (66.67)	1 (33.3)	
Gender	Male	48 (44.04)	37 (77.08)	11 (22.92)	**0.173**
	Female	61 (55.96)	53 (89.66)	7 (10.34)	
Age category	18 – 20	9 (8.25)	7 (77.78)	2 (22.22)	**0.234**
	21 – 30	35 (32.11)	25 (73.53)	10 (26.47)	
	31 – 40	26 (23.85)	24 (92.31)	2 (7.69)	
	41 – 50	17 (15.56)	14 (82.35)	3 (17.65)	
	>51	22 (20.18)	21 (95.45)	1 (4.54)	
Marital status	Married	64 (58.71)	58 (90.63)	6 (9.38)	**0.14**
	Single	35 (32.11)	25 (71.43)	10 (28.57)	
	Others	10 (9.17)	9 (9.78)	1 (5.88)	
Education level	Not attend school	8 (7.47)	7 (87.50)	1 (12.50)	0.863
	Primary	14 (13.08)	13 (92.86)	1 (7.14)	
	Junior Sec	23 (21.49)	19 (82.61)	4 (17.39)	
	Senior Sec	32 (29.90)	27 (84.38)	5 (15.63)	
	Tertiary	30 (28.04)	24 (80.00)	6 (20.00)	
Farm location	Urban	34 (32.07)	28 (82.35)	6 (17.65)	0.481
	Peri-urban	47 (44.34)	42 (89.36)	5 (10.64)	
	Rural	25 (23.58)	19 (76.00)	6 (24.00)	

Results also indicated that most broiler farmers had houses with electricity (89.62%) and kept chickens in backyard poultry houses (84%). Some of the farmers (16.98%) kept birds of different age groups together in the same poultry house without separation. The majority (92.59%) of the poultry houses were not fenced. Most (90.8%) of the poultry houses had concrete floors, and 64.2 per cent had no drainage system, and the destination for the drainage was mainly open land and fields (Table 3).

Table 3: Univariate analysis of the farm characteristics factors for AMR on broiler poultry farms (n=109)

Variable	Level	Positive n (%)	Negative n (%)	p-value
Sources of drinking water	Pipe	49 (90.74)	5 (9.26)	0.035
	Borehole/ well	31 (73.81)	11 (26.19)	
	Others	9 (90.00)	1 (10.00)	
Electricity	Yes	79 (83.16)	16 (16.84)	0.141
	No	11 (100.00)	0 (0.00)	
Poultry house in the backyard	Yes	76 (85.39)	13 (14.61)	0.358
	No	13 (76.47)	4 (23.53)	
Poultry farm type	All in all, out	58 (85.29)	10 (14.71)	0.704
	Continuous	30 (81.08)	7 (18.92)	
Poultry housing type	Open sided type	44 (83.02)	9 (16.98)	0.058
	Close sided type	41 (87.23)	6 (12.77)	
Floor house type	Concrete	85 (85.86)	14 (14.14)	0.188
	Soil	7 (70.00)	3 (30.00)	
Drainage system present	Yes	30 (76.92)	9 (23.08)	0.108
	No	62 (88.57)	8 (11.43)	
Drainage destinations	Land	59 (89.39)	7 (10.61)	0.005
	Fields	23 (71.88)	9 (28.13)	
	Others	8 (88.89)	1 (11.11)	
Different ages are kept together.	Yes	15 (83.33)	3 (16.67)	0.896
	No	75 (85.23)	13 (14.77)	
Facility to isolate sick birds	Yes	37 (88.10)	5 (11.90)	0.633
	No	55 (83.33)	11 (16.67)	
Sources of feed	Self-formulated	1 (50.00)	1 (50.00)	0.349
	from feed company	86 (86.00)	14 (14.00)	
	Both	4 (80.00)	1 (20.00)	
House fenced	Yes	8 (100.00)	0 (0.00)	0.22
	No	84 (84.00)	16 (16.00)	

The common diseases reported on the broiler poultry farms were diarrhoea (79.81%), cough and flu (11.54%) and others (Table 4). Most (95.0%) poultry farmers used antibiotics, and 60.40% bought the antibiotics without a prescription. In addition, 37.25% of the farmers used antibiotics as growth promoters for the birds (Table 4).

Table 4: Univariate analysis of the farm management practices factors for AMR on broiler poultry farms (n=106)

Variable	Level	Positive n (%)	Negative (%)	p-value
Recycle beddings	Yes	7 (87.50)	1 (12.50)	0.831
	No	83 (84.69)	15 (15.31)	
Bedding use	Manure	88 (83.81)	17 (16.19)	0.535
	Others	2 (100.00)	0 (0.00)	
Bird population	< 500	43 (84.31)	8 (15.69)	**0.212**
	500 - 1000	11 (91.67)	1 (8.33)	
	Above 1000	5 (62.50)	3 (37.50)	
Mix bird species	Yes	4 (80.000	1 (20.00)	0.871
	No	86 (85.15)	15 (14.85)	
Birds reared purpose	Meat for sale	7 (77.78)	2 (22.22)	0.567
	Sale and home consumption	85 (85.00)	15 (15.00)	
Poultry origin	Same company	14 (82.35)	3 (17.65)	0.373
	Different company	46 (90.20)	5 (9.80)	
	Not known	32 (80.00)	8 (20.00)	
Personnel restricted house	Yes	75 (83.33)	15 (16.67)	0.633
	No	12 (92.31)	1 (7.69)	
Other domestics animal	Yes	55 (84.62)	10 (15.38)	0.958
	No	34 (85.00)	6 (15.00)	
Use of protective gears	Yes	62 (81.58)	14 (18.42)	0.104
	No	30 (93.75)	2 (6.25)	
Rats on the farms	Yes	49 (84.48)	9 (15.52)	0.888
	No	39 (82.98)	8 (17.02)	
Common diseases of birds	Cough & flu	11 (91.66)	1 (8.33)	0.602
	Diarrhoea	69 (83.13)	14 (16.86)	
	Other	8 (88.88)	1 (12.5)	
Use of antibiotics to treat birds	Yes	80 (85.11)	14 (14.89)	0.756
	No	4 (80.00)	1 (20.00)	
Buy antibiotics in a retail shop.	Yes	19 (21.84)	68 (78.16)	0.332
	No	5 (33.33)	10 (66.66)	
Buying antibiotics from a Vet clinic	Yes	70 (80.46)	17 (19.54)	0.528
	No	11 (73.33)	4 (26.66)	
Buying from Vet personnel	Yes	1 (1.15)	86 (98.85)	0.155
	No	1 (6.66)	14 (93.33)	
Drug prescription when buying	Yes	18 (78.26)	5 (21.74)	0.135
	No	54 (88.52)	7 (11.48)	
	Unknown	12 (70.14)	5 (29.41)	
Administered by vet personnel	Yes	14 (14.14)	3 (50.00)	0.021
	No	85 (85.86)	3 (50.00)	
Admin by trained farmer	Yes	79 (84.95)	9 (75.00)	0.379
	No	14 (15.05)	3 (25.00)	
Admin by untrained farmer	Yes	56 (87.50)	32 (78.05)	0.2
	No	8 (12.50)	9 (21.95)	
Admin by owner	Yes	52 (80.00)	13 (20.00)	0.177
	No	36 (90.00)	4 (10.00)	
Use of growth promoter	Yes	33 (86.84)	5 (13.16)	0.588
	No	53 (82.81)	11 (17.19)	

Potential Risk Factors

Univariate analysis of demographic factors for AMR of broiler poultry farms

Table 2 shows cross-tabulation results of the outcome variable, 'farm-AMR-status' and hypothesised demographic characteristics in Chi^2-analysis. Three variables, namely; gender, the age category of farmers, and marital status, which had *P*< 0.25 in univariate analysis, were candidate variables for the multivariable logistic model.

Univariate Analysis of Farm Characteristics for AMR of Broiler Poultry Farms

Table 3 shows cross-tabulation results of the outcome variable 'farm-AMR-status' and hypothesised farm characteristics factors in Chi^2 analysis. Variables, 'sources of drinking water, 'electricity, poultry housing type', 'floor housing type', 'presence of drainage system' and 'destination of the drainage', which had *P*< 0.25, were taken for further screening in the logistic model.

Univariate Analysis of Factors Related to Farm Management Practices for AMR of Broiler Poultry Farms

Table 4 shows cross-tabulation results of the outcome variable 'farm-AMR-status' and hypothesised farm management risk factors in Chi^2 analysis. Variables; 'bird population', 'use of protective gear', 'buying drugs from veterinary personnel', 'drug-prescription when buying', 'drugs administered by veterinary personnel', 'drugs administered by a trained farmer', and 'administered by owner' which had *p*< 0.25 and were taken for further screening in the logistic model.

Logistic regression model and validation

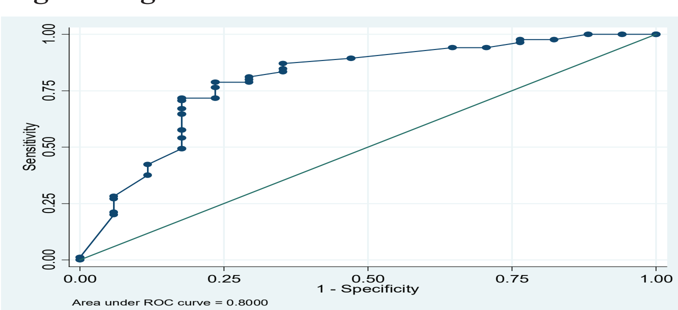

Figure 01: ROC curve demonstrating predictability of the model

The Pearson Chi-square goodness-of-fit test (*p* = 0.486) showed that the model fitted the data, thus increasing its reliability in predicting AMR farm status. The Receiver-Operating characteristic curve analysis (Figure 1) demonstrated that the model was good in predicting farm-AMR status (ROC=0.8).

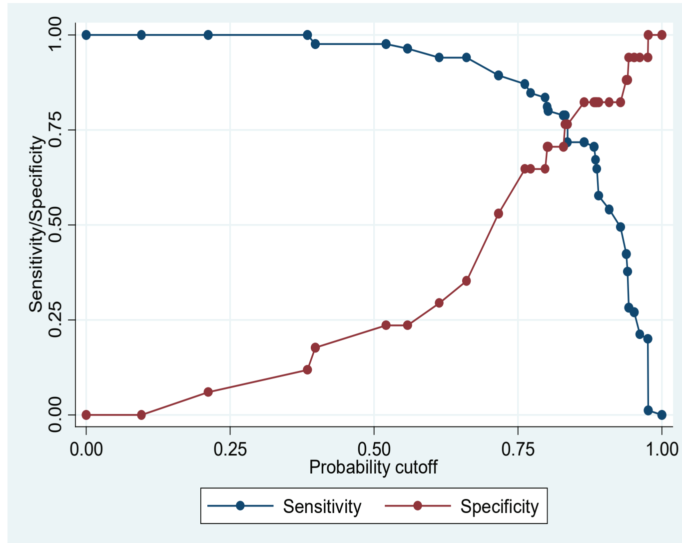

Figure 02: Graphs demonstrating probability cut-off vs sensitivity and specificity.

The model had relatively high sensitivity and specificity in classifying the farm as having an AMR problem or not (Figure 2).

Table 5: Multivariate analysis of factors for AMR in broiler farms

Variable	Odds ratio	95% CI	*P*-value
Gender			
Male	Ref	Ref	
Female	2.54	0.74 - 8.74	0.14
Marital status			
Single	Ref	Ref	
Married	4.04	1.15–14.17	**0.03**
Others	1.514	0.131-17.48	0.74
Administered by vet personnel			
No	Ref	Ref	
Yes	11.91	1.28 - 110.86	**0.03**
Admin by untrained farmer			
No	Ref	Ref	
Yes	2.02	0.58 - 7.01	0.26
Drainage destination			
Fields/Garden	Ref	Ref	
Land	3.12	0.88 – 11.02	0.08
Others	3.21	0.30 – 34.41	0.33

The multivariate logistic regression model showed that marital status and administration of drugs by veterinary personnel or the farmer were predictors of a broiler chicken farm having an antimicrobial resistance problem (Table 5). The odds of a female-managed farm having an AMR problem was 2.5 (95% CI: 0.74-8.74) higher than that managed by a male farmer, the reference group.

The odds of a farm managed by a married person with an AMR problem was 4.0 (95% CI: 1.15-14.17) higher than that managed by a single person, a reference group. The odds of a farm having an AMR problem where the drugs were administered by other personnel to broiler chickens were 11.91 (95% CI; 1.28 – 110.86) times higher than the one where drugs were administered by the veterinary personnel (reference group). Further, the odds of a farm having an AMR problem where untrained farmers administered the drugs were 2.02 (95% CI: 0.58 – 7.00) higher than the farm where a trained farmer administered the drugs (reference group). The odds of the farm being AMR positive where drainage flowed out to the land was 3.1 (95% CI: 0.88 – 11.02), compared to farms where drainage flowed out to other destinations 3.2 (95% CI: 0.30 – 34.41); and higher than the farms where the drainage was flowing out to the fields/garden as the reference group.

Discussion

This study determined the risk factors associated with AMR on broiler poultry farms in the selected districts of Zambia. The majority of the broiler farmers were small-scale and married. More females (56%) took part in broiler production than males. Because of the low capital for start-up and a high return on investment for broiler production, women are able to venture into this business to contribute to income generation for school fees, household food, and nutrition security. This is consistent with a study carried out in Tanzania and Zambia that showed that women are more engaged and are the key beneficiaries of chicken production (Queenan *et al.*, 2016).

This study also showed that most broiler farmers (89.6%) had houses with electricity. Moreover, most farmers (84%) also kept chickens in the backyard poultry houses, and 95 per cent of the houses were not fenced. A review by Conan (2012) reported that poultry represents an essential sector in animal production, with backyard flocks representing a huge majority, especially in developing countries. Backyard production methods imply low biosecurity measures and a high risk of infectious diseases.

The study showed that the common group of diseases encountered on broiler poultry farms were diarrhoeal diseases (79.8%) and respiratory diseases (11.5%). Most poultry farmers (95.0%) used antibiotics and bought the antibiotics without a prescription. In addition, more than one-third of the farmers used antibiotics as growth promoters for the birds. A review by Mund *et al.* (2017) reported that the use of antibiotics in poultry is an everyday disease management practice in developing countries and that the most commonly used antibiotics were Tetracycline, gentamicin, neomycin, tylosin, erythromycin, virginiamycin, ceftiofur, and bacitracin.

This study showed an overall poultry farm-level AMR prevalence of 84.4 per cent which was high. Comparable prevalence results among the study districts showed that Ndola, Choma, and Kafue had the highest farm level AMR prevalence of 87.1 per cent, 88.9% per cent and 86.4 per cent, respectively. The other districts, Chilanga (78.6%) and Kitwe (73.3%) showed a slightly lower prevalence. The reasons for these differences are not easily discernible and could be the subject of another study. The current findings are higher than what has been reported from different countries, 15.12 per cent from Modjo (Ethiopia), 32 per cent from Dhaka (Bangladesh), 41.9 per cent from Jimma (Ethiopia), 10 per cent from Zimbabwe, 12 per cent from Kenya (Makaya *et al.*, 2012; Kindu and Addis, 2013; Abunna *et al.*, 2016; Karim *et al.*, 2017; Ngai *et al.*, 2021), 40 per cent among the poultry farms in Colombia (Gardner *et al.*, 2012), 34.4 per cent among the poultry farms in Algeria (Djeffal *et al.*, 2018) and 48-65 per cent among chickens in China (Cui *et al.*, 2016; Yu *et al.*, 2018). Although the reason behind such differences in AMR prevalence is unclear, several factors can contribute to such variations such as differences in the definition of what is termed 'positive AMR farm', differences in sample collection techniques, season, and bacterial identification methods, and country policy on the use of antibiotics for growth promotion, observed bio-security in poultry, AMR surveillance, and regulation enforcement.

The high prevalence of AMR on poultry farms could be attributed to the low levels of poultry farm biosecurity associated with lack of biosecurity knowledge; sources of breeding stock, availability and easy accessibility of antibiotics; and disease burden, particularly for small scale to prevent high morbidity and mortality rates (Muonga *et al.*, 2020); and easy access of information on antibiotics for prevention hence widespread usage of a wide range of these antibiotics for prophylaxis and treatment (Phiri *et al.*, 2020).

Some farmers (49.5%) in this study reported using municipality water; among these, 44.9 per cent had farms associated with AMR. However, this study did not identify the water source as a significant risk factor for AMR. A study in Bangladesh (Mandal *et al.*, 2022) showed that the water source for poultry was significantly associated with AMR occurrence because the people and livestock would swim in the same water used for other household purposes, resulting in contamination.

The study showed that most poultry houses had concrete floors (90.83%). A high number of poultry houses (64.22%) had no drainage system; the drainage destination was mainly open land and fields and was associated with AMR. These factors are related to poor hygiene practices, which are known risk factors for AMR. Drainage system destination increased the risk of AMR occurrence on poultry farms, which could be attributed to the dissemination of resistant bacteria in the farm environment. The spread of the effluent into the environment could lead to subsequent contamination of vegetables, other livestock on the farm and the aquatic environment, and ultimately to humans. Vegetables may get contaminated by applying contaminated manure on agricultural lands as fertiliser and watering crops with contaminated water, among others, thus pausing a public health risk of AMR. Many antibiotics can persist in the environment and are detected in drinking water (Ye *et al.*, 2007; Larsson, 2014). Antimicrobial resistance can spread in the environment through horizontal and vertical gene transfers via mutation and recombination, and most resistance genes transferred to pathogenic bacteria through horizontal gene transfer originate from bacteria living in the environment (Larsson, 2014; Praveenkumarreddy *et al.*, 2020). Antimicrobials administered in poultry farming remain the leading driver of AMR environmental pollution in Egypt (Hedman *et al.*, 2020). Environments with sustained excretion of resistant determinants substantially alter the soil microbiome (Hedman *et al.*, 2020). Besides the risk of favouring microbial antibiotic resistance, plants can absorb antibiotic residues, interfering with physiological processes and causing potential ecotoxicological effects (Larsson, 2014).

Thirty per cent of the farmers did not use any protective gear. Use of separate shoes and clothes for the poultry house, and wearing head covering and masks prevent transmission of infectious organisms from humans to poultry and vice versa. Shared materials between humans and animals may contribute to the transmission of antibiotic-resistant bacteria (Mandal *et al.*, 2022).

As expected, farms with high bird stocking densities were more likely to have AMR problems. This was mainly a problem among small-scale backyard farmers. This is because high bird population density compromises hygiene standard and promote disease transmission between infected and susceptible birds, a situation that may lead to the use of antimicrobials. Moreover, the study by Mandal *et al.* (2022) reported that the stocking density of birds was a risk factor for the occurrence of antibiotic-resistant *E. coli* in broilers.

The multivariable logistic regression model identified marital status administration of drugs by veterinary personnel or the farmer as predictors of a broiler chicken farm having an AMR problem. The married, particularly women, were significantly associated with AMR problems as the odds for AMR problems were four times higher in married persons than for single persons. This was because most married women were involved in several household activities such as taking care of children such as bathing them, changing nappies, cooking, and general cleaning in and outside their homes, exposing them to contamination and cross contamination from various sources. A busy schedule could also compromise time spent on managing the birds. Accompanied by low biosecurity measures on poultry farms, they may transmit the infectious agents to the poultry houses and from poultry houses to their homes.

Drug prescription and administration by trained personnel or veterinary personnel were statistically significant to farm AMR. Further, the odds of having farm bacterial AMR were twelve times higher in farms where drugs were administered by other personnel or untrained farmers than when administered by veterinary personnel. This could be due to a lack of veterinary drug knowledge that could lead to misuse, such as the administration of sub-therapeutic dosages in food animals (Abdi *et al.*, 2017). In addition, a study by Talukder *et al.* (2021) from Bangladesh stated that poultry farms with farmers who had less knowledge of drug administration were at high risk of developing AMR. One of the major concerns is the over-the-counter sale of antibiotics without prescription, which promotes the irrational use, overuse, and misuse of antibiotics in the animal health andhuman health sectors in most developing countries, including Zambia (Masich *et al.*, 2020; Matin *et al.*, 2020; Orubu *et al.*, 2021). Subsequently, indiscriminate use of antibiotics without prescription contributes to the development and spread of AMR (Ayukekbong *et al.*, 2017).

Conclusion

The high prevalence of bacterial AMR in broiler farms suggests a greater antimicrobial use in broiler poultry production in Zambia, indicating a public health concern. The present study identified marital status, administration of drugs by veterinary personnel or the farmer and farm management practices as factors contributing to increased AMR occurrence on the farms.

The factors such as low bio-security levels on the farms and the occasional use of personal protective gear when dealing with poultry, as well as a great degree of overlap between the farming and household environment, compound the problem of AMR. The government of Zambia should strengthen education and awareness on AMR and other food safety pre-requisite programmes such as Good Hygiene Practices (GHPs and Good Manufacturing Practices (GMPs), particularly for small-scale farmers. There is also a need to implement an effective, well-coordinated AMR surveillance system to monitor the trends for policy direction and strict regulations for selling and using antibiotics.

Article Information

Funding: This research was funded by the WHO-Advisory Group for Integrated Surveillance of Antimicrobial Resistance (AGISAR) project, grant number/ Reference ID 204954.

Conflicts of Interest: The authors declare no conflict of interest.

Acknowledgments: The researchers greatly appreciate the valuable contributions of all who participated in the study from the study sites. They would also like to thank the WHO-AGISAR Project for funding and every team member who took the time to participate in this study.

Authors contribution. Prof. JBM, Dr. GM, Dr. MM and Mr. RM conceived and designed the study idea. Dr. MM, Mr. RM, Dr. NP, Ms. EMM and Ms. MM were involved in field data collection. Dr. MM, Mr. RM, Dr. EM, Dr. CM and Prof. MM cleaned and analysed the data. Dr. MM, Mr. RM, Dr. SM and Prof. JBM were involved in the interpretation of the results. Dr. MM and Prof. JBM drafted the manuscript. Dr. FB, Prof. MM Dr. GM and Dr. EM, reviewed and Dr. EM edited the manuscript. Dr. GM and Dr. MM coordinated the field work. Prof. JBM coordinated the overall study All authors contributed to the article and approved the submitted version.

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