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ANTIBIOTIC PROPHYLAXIS AND CLOACAL CARRIAGE OF RESISTANT ZOONOTIC BACTERIA IN COMMERCIALLY-BRED POULTRY

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Abstract

Purpose: The aim of this study was to determine the relationship between the use of antibiotic prophylactics in commercial poultry breeding and cloacal carriage of antibiotic-resistant zoonotic bacteria.

Methodology: Biodata was collected on poultry from 11 selected farms. Cloacal swabs were collected from 10 birds from each farm for culture, isolation and biochemical identification of bacteria isolates. Antibiotic susceptibility of 96 Enterobacteriaceae and 24 *Staphylococcus aureus* isolates were determined by disk diffusion.

Findings: Antibiotics prophylaxis administered to the birds were chloramphenicol (40/110), penicillin (20/110), doxycycline (20/110), gentamicin (10/110), neomycin (10/100) and a combination of chloramphenicol, ampicillin, penicillin and cloxacillin (10/100). These were administered either weekly (90/110), every 3 days (10/110) or monthly (10/100). Two hundred and fifty six (256) different bacteria isolates were recovered. These were *Escherichia coli* (31.6%), *Staphylococcus aureus* (14.5%), *Staphylococcus epidermidis* (12.1%), *Proteus sp*. (12.1%), *Citrobacter sp*. (9%), *Proteus vulgaris* (5.1%), *Salmonella enterica* (4.7%), *Citrobacter koseri* (4.3%), *Klebsiella sp*. (2.8%), *Klebsiella pneumoniae (2.3%)*, *Shigella sp*. (2.3%), *Enterobacter sp*. (0.8%) *and Klebsiella oxytoca (0.4%)*. Of 96 Enterobacteriaceae, 60 (63%) were multidrug resistant. Enterobacteriaceae were resistant to ampicillin (54%), tetracycline (52%), cotrimoxazole (54%), gentamicin (22%), cefuroxime (44%), vancomycin (19%), chloramphenicol (39%), ceftriaxone (29%), cefotaxime (71%), ciprofloxacicn (21%), amikacin (10%) and meropenem (23%). Of 24 *Staphylococcus aureus*, 17 (71%) were multidrug resistant. *Staphylococcus aureus* were resistant to ampicillin (89%), cotrimoxazole (59%), gentamicin (24%), vancomycin (67%), ciprofloxacin (18%), meropenem (33%), tetracycline (85%), cloxacillin (100%), penicillin (81%), erythromycin (71%), cefuroxime (43%) and augmentin (45%). Doxycycline-prophylaxis was significantly related (0.001) to tetracycline-nonsusceptible isolates but chloramphenicol-prophylaxis and penicillin-prophylaxis were not significantly related (<0.05) to resistance to their corresponding antibiotics.

Unique contribution to theory, practice and policy*:* Occurrence of multidrug resistant zoonotic bacteria was high as was the frequency of administering antibiotic prophylactics. Amikacin was the most effective antibiotic against Enterobacteriaceae whereas gentamicin and ciprofloxacin were the most effective against both Enterobacteriaceae and *Staphylococcus aureus*. To safeguard high-priority class antibiotics regulations to adhere to the WHO statement on the use of antibiotics in animal husbandry should be enforced. Alternative measures should also be applied to reduce dependence on antibiotics in poultry farming.

Keywords: *Antibiotics, prophylactics, zoonotic, poultry, resistant*

1. INTRODUCTION

1.1 Background of the Study

Antibiotic abuse has been described as being the most vital selecting force for antibiotic resistant bacteria in both veterinary and human medicine (Akond, Alam, Hassan, & Shirin, 2009). Poultry can be a major source for the emergence, selection and transmission of antibiotic resistant bacteria to humans firstly because they carry zoonotic bacteria and secondly because the common antibiotics given to humans for treatment are frequently used by farmers as prophylactics, treatment and growth promoters for their birds (Mwambete & Stephen, 2015). About 60-73% of the world's antibiotics produced have been reported to find their way in both therapeutic and nontherapeutic applications in animal breeding (Agyare, Boamah, Zumbi & Osei, 2018; Ryan, 2018). This may account for the selection and spread of antimicrobial resistant bacteria (Shecho, Thomas, Kemal, & Muktar, 2017) because the gut of poultry serves as an important reservoir of bacteria of diverse species (Clavijo & Flórez, 2017).

Antibiotic resistant bacteria selected through drug pressure (Shecho, Thomas, Kemal & Muktar, 2017) may multiply in the gut and become vehicles for transferring resistance to human pathogens (Argudin et al., 2019). Horizontal transfer of antibiotic resistant genes through plasmids may occur and lead to further resistance of other bacteria in the gut which potentially can spread to humans through contamination of the plumage, flesh and eggs via poultry litter (Akond *et al.*, 2009; Dale & Brown, 2013). Through improper treatment and disposal, bacteria in poultry litter used in agro fields as manure or from the poultry farms may end up in run-off water during rains (Bushan, Khurana, Sinha & Nagaraju, 2017) and contaminate farm produce as well as the environment.

The common practice of administering prophylaxis on a frequent basis by poultry farmers raises concerns because resistance patterns of some antibiotics have been attributed to their widespread, indiscriminate and lengthy use. The European Union (EU) in an attempt to ensure antibiotic stewardship is banning the prophylactic use of antibiotics in farming following the WHOs call to end preventive group treatments of farm animals using high-priority class antibiotics which are important in human medicine (Ryan, 2018). Current poultry breeding practices in Ghana such as indiscriminate use of antibiotics and questionable sanitation conditions in the pens may favour the selection and spread of antibiotic resistant bacteria in the gut of birds. Rasmussen, Opintan, Frimodt-Moller & Styrishave (2015) in a study using *Escherichia coli* isolates from local and imported poultry showed that markers for tetracycline-resistance were more frequent in the local than in the imported poultry.

1.2 Problem Statement

Since no new antibiotics have been developed in the modern era (Agyare et al, 2018) it is important to study how antibiotic prophylaxis used in poultry farming impacts on the prevalence of antibiotic resistant bacteria because apart from posing a public health threat, these may lead to bird mortalities and cause economic losses to farmers (Nhung, Chnasiripornchai, Juan & Carrique-Mas, 2017). Studies on antibiotic resistant bacteria in poultry across the country have frequently focused on isolating bacteria from pens or flesh of slaughtered birds. The challenge with this is that such samples may be contaminated with bacteria from the environment. Rasmussen et al. (2015) worked on *E. coli* isolates from the cloaca of live poultry chicken but did not consider other zoonotic bacteria resident in the cloaca of poultry birds hence there is a paucity of information on the impact of antibiotic prophylaxis on zoonotic bacteria resident in the gut of live poultry birds. By determining the antibiogram of these zoonotic bacteria in relation to the prophylactics administered by farmers the impact and extent of the antibiotic resistance menace will be further defined and effective alternative antibiotics can be recommended.

1.3 Research Objective

The objective of the study was to find the relationship between the use of antibiotic prophylactics in commercial poultry breeding and cloacal carriage of antibiotic-resistant zoonotic bacteria.

2. MATERIALS AND METHODS

2.1 Sample Collection

The study was a cross sectional study conducted from March to June, 2019. Eleven large and medium holding capacity poultry farms that breed chicken for commercial purposes in the western districts of Greater Accra Region were selected for sampling. Locations included Bubiashie, North Kaneshie, Kaneshie, Tabora, Asylum Down, Ayimensah, Oyarifa, Kpone, Nungua and Osu. Data on age and breed of birds, rate of prophylaxis and type of antibiotic prophylactic were recorded. Ten (10) Cloacal swab specimen were collected from live poultry chicken from each farm. The birds were randomly selected and marked out after collecting each specimen to prevent double sampling. Samples were transported in sterile peptone broth for processing at the Microbiology Laboratory of the Department of Science Laboratory Technology of Accra Technical University.

2.2 Isolation and Identification of Bacteria

Bacteria were isolated on Nutrient Agar (Biomark), MacConkey Agar (Biomark) and Mannitol Salt Agar (Oxoid). Preliminary identification of isolates was done using colony morphology on MacConkey Agar for Enterobacteriaceae and Mannitol Salt Agar for Staphylococci. Isolates were Gram stained. Catalase test was performed on Gram positives from Mannitol Salt Agar. Gram negatives were further identified by urea, citrate, indole, Kligler's reaction test, catalase and oxidase test.

2.3 Antimicrobial Susceptibility Testing

The sensitivity of selected Enterobacteriaceae and *Staphylococcus aureus* isolates to different antibiotics was determined using the Kirby-Bauer method. Using disk obtained from Biomark Laboratories Gram positive bacteria were tested for susceptibility to penicillin (1.5ug), ampicillin (10ug), cloxacillin (5ug), erythromycin (5ug), tetracycline (30ug), vancomycin (30ug), cotrimoxazole (25ug), cefuroxime (10ug), gentamicin (10ug), ciprofloxacin (5ug), augmentin (30ug) and meropenem (10ug). Gram negative bacteria were tested for susceptibility to ampicillin (10ug), tetracycline (10ug), cotrimoxazole (10ug), gentamicin (10ug), cefuroxime (30ug), vancomycin (30ug), chloramphenicol (10ug), ceftriaxone (30ug), cefotaxime (30ug), ciprofloxacin (5ug), amikacin (30ug) and meropenem (10ug). Controls were set using *Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 29213. Zone sizes were interpreted according to CLSI 2018 guidelines on antimicrobial susceptibility testing.

2.4 Data Analysis

Data was captured on Microsoft Excel and imported to IBM SPSS Statistics 20 for descriptive analysis using cross tabulations. Pearson's coefficient was used to determine the relation between antibiotic-prophylaxis of chloramphenicol, doxycycline and penicillin to nonsusceptibility, which is intermediate and resistant responses, of bacteria isolates to antibiotics of the same type or in the same class as the prophylactic administered. P values <0.05 were considered as statistically significant.

3. Results

3.1 Biodata of Selected Poultry

The age of the birds, their breed and prophylaxis on the selected farms are presented in Table 1.

Table 1: Biodata of Selected Poultry

Age and Prophylaxis Administered to Breeds of Birds at 11 Selected Poultry Farm Sites.

Farm Code	Age (Weeks)	Breed		Prophylaxis	
		Broilers	Layers	Rate	Prophylactic(s)
LF	8-16	10	-	Weekly	Chl, Amp, Pen, Clox
OF	8-16, 32	-	10	Weekly	Pen
SF	9	10	-	Weekly	Chl
KF	16	10	-	Weekly	Dox
MK	32	10	-	Monthly	Dox
TF	8-16, 32	5	5	Weekly	Chl
FV	8-12	10	-	Weekly	Pen
NA	4-32	10	-	Weekly	Chl
AF	16-32	10	-	Weekly	Chl
NE	36	-	10	3 days	Neo
JF	6	-	10	Weekly	Gen

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Note. The antibiotics administered were ampicillin (Amp), penicillin (Pen), chloramphenicol (Chl), doxycycline (dox), neomycin (Neo) and gentamicin (Gen).

As shown in Table 1, the 11 poultry farm sites from which samples were collected were coded LF, OF, SF, KF, MK, TF, FV, NA, AF, NE and JF. The ages of the birds ranged from 4 to 32 weeks.

Of 110 birds, 70 broilers from sites LF, SF, KF, MK, FV, NA and AF and 30 layers from sites OF, NE and JF were sampled. Of 110 birds, 5 layers and 5 broilers from site TF were sampled.

Of 110 birds, 85 from sites LF, OF, SF, KF, TF, FV, NA, AF and JF were administered antibiotic prophylactics weekly, 10 birds from site MK were administered antibiotic prophylactics monthly and 10 birds from site NE were administered antibiotic prophylactics every three days.

3.2 Resident Zoonotic Bacteria

Frequency distribution of zoonotic bacteria (n=256) from cloaca of selected live poultry chicken.

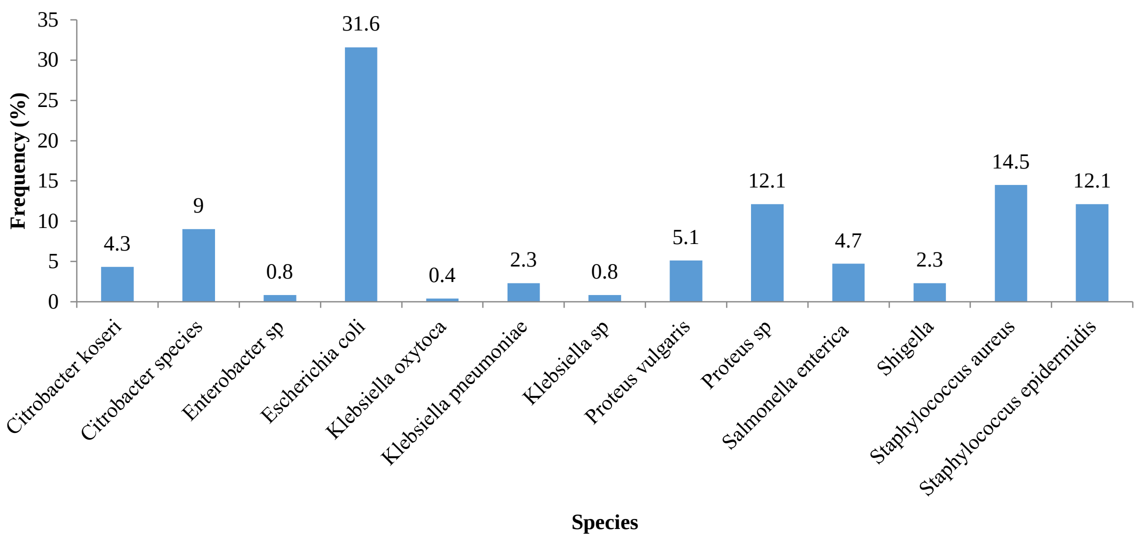

Figure 1: Resident Zoonotic Bacteria

Two hundred and fifty six (256) bacteria were successfully recovered and identified from 110 cloacal swab specimen. Of these, 188 (73%) were Enterobacteriaceae and 68 (27%) were staphylococci. Of the total staphylococci, 54% were *Staphylococcus aureus* and 46% were *Staphylococcus epidermidis*.

As shown in Figure 1, the bacteria isolates identified were *Citrobacter koseri* (4.3%), *Citrobacter sp*. (9%), *Enterobacter sp.* (0.8%), *Escherichia coli* (31.6%), *Klebsiella sp*.(3.5%), *Proteus sp*.(12.1%), *Proteus vulgaris* (5.1%), *Salmonella enterica* (4.7%), *Shigella sp*. (2.3%), presumptive *Staphylococcus aureus* 37(14.5%) and *Staphylococcus epidermidis* 31(12.1%).

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3.3 Antibiogram of Enterobacteriaceae

Antibiogram of Enterobacteriaceae (n = 96) from Cloaca of Live Poultry.

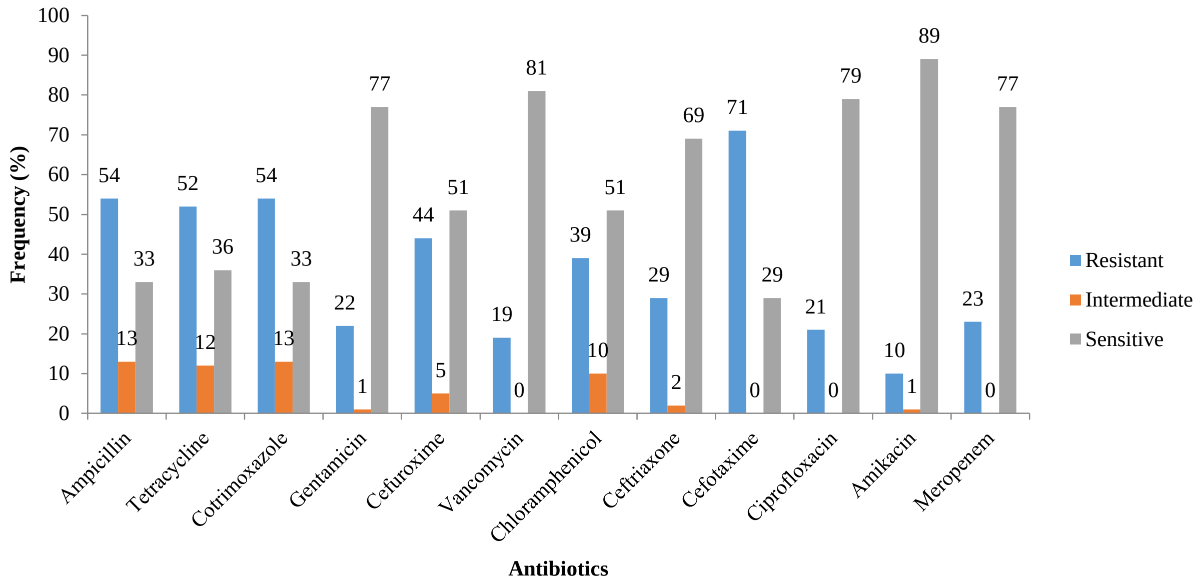

Figure 2: Antibiogram of Enterobacteriaceae

Of 96 Enterobacteriaceae isolates screened 60 (63%) were found to be multidrug resistant.

As shown in Figure 2, the prevalence of resistance to cefotaxime (71%) was high (>60% of total tested). The prevalence of resistance to ampicillin (54%), tetracycline (52%), cotrimoxazole (54%) and cefuroxime (44%) were moderate (40-60% of total tested). The prevalence of resistance to gentamicin (22%), vancomycin (19%), ceftriaxone (29%), ciprofloxacin (21%), amikacin (10%) and meropenem (23%) were low (<40% of total tested).

A high prevalence of Enterobacteriaceae susceptible to gentamicin (77%), vancomycin (81%), ceftriaxone (69%), ciprofloxacin (79%) and meropenem (77%) were found.

3.4 Antibiogram of *Staphylococcus aureus*

Antibiogram of *Staphylococcus aureus* (n = 24) from Cloaca of Live Poultry.

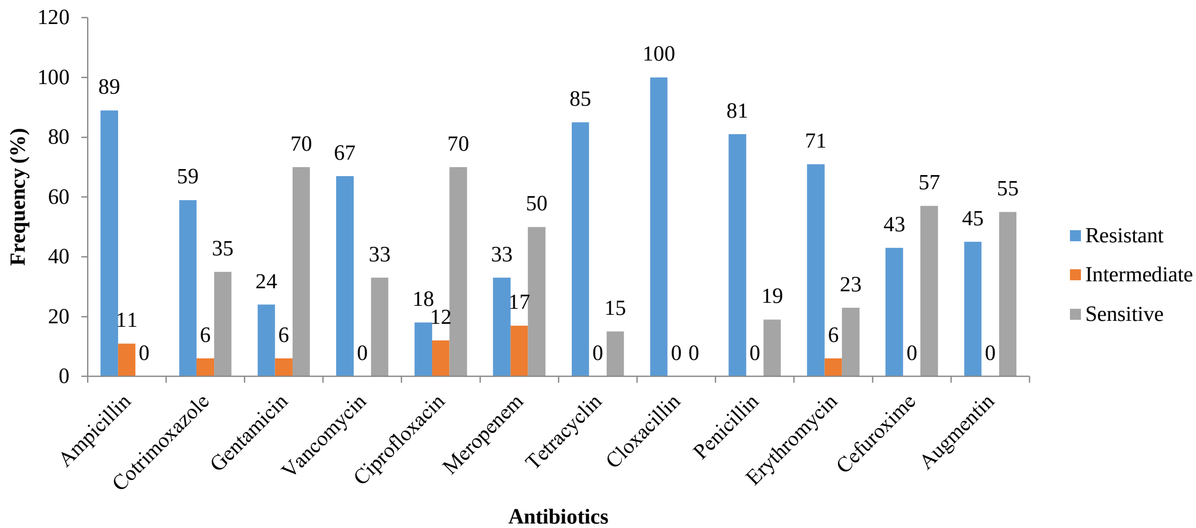

Figure 3: Antibiogram of *Staphylococcus aureus*

Of 24 *Staphylococcus aureus* isolates screened 17 (71%) were found to be multidrug resistant.

As shown in Figure 3, the prevalence of resistance to ampicillin (89%), vancomycin (67%), tetracycline (85%), cloxacillin (100%), penicillin (81%) and erythromycin (71%) were high (>60% of total tested). The prevalence of resistance to cotrimoxazole (59%), cefuroxime (43%) and augmentin (45%) were moderate (40-60% of total tested). The prevalence of resistance to gentamicin (24%), ciprofloxacin (18%) and meropenem (33%) were low (>40% of total tested).

A high prevalence of *Staphylococcus aureus* susceptible to gentamicin (70%) and ciprofloxacin (70%) were found.

3.5 Resistance to Farm Administered Prophylactic

Antibiotic resistance of Enterobacteriaceae and *Staphylococcus aureus* to prophylaxis given to the birds at the selected farms are presented in Table 2.

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Table 2: Resistance to Farm Administered Prophylactic

Frequency of Resistance to Class of Antibiotic Prophylactic Administered at 9 Poultry Farm Sites

Farm Code	Prophylactic Administered	% Resistant to Class of Prophylactic	
		Enterobacteriaceae	*S. aureus*
LF	Chloramphenicol	Chloramphenicol (20)	-
	Ampicillin	Ampicillin (15)	-
	Penicillin	-	Penicillin (67)
	Cloxacillin	-	Cloxacillin (100)
OF	Penicillin	Ampicillin (25)	-
SF	Chloramphenicol	Chloramphenicol (23)	-
KF	Doxycycline	Tetracycline (100)	-
MK	Doxycycline	Tetetracycline (90)	Tetracycline (100)
TF	Chloramphenicol	Chloramphenicol (44)	-
FV	Penicillin	Ampicillin (78)	-
NA	Chloramphenicol	Chloramphenicol (18)	-
AF	Chloramphenicol	Chloramphenicol (47)	-

As shown in Table 2, chloramphenicol was the most widely administered prophylactic (5/11). This was followed by penicillin (3/11) and doxycycline (2/11). Ampicillin, cloxacillin and gentamicin were each administered as prophylactic antibiotics on one farm each (1/11).

OF and FV administered only penicillin prophylactic. KF and MK administered only doxycycline prophylactic. SF, TF, NA and AF administered only chloramphenicol prophylactic. NF administered only neomycin prophylactic and JE administered only gentamicin prophylactic. LF administered chloramphenicol, ampicillin, penicillin and cloxacillin prophylactics.

Farms that administered penicillin prophylactic (2/11) had 25% (OF) and 78% (FV) resistance to ampicillin among the Enterobacteriaceae. Farms that administered ampicillin prophylactic (1/11) had 15% (LF) resistance to ampicillin among the Enterobacteriaceae. Farms that administered chloramphenicol prophylactic (5/11) had 20% (LF), 23% (SF), 44% (TF), 18% (NA) and 47% (AF) resistance to chloramphenicol among the Enterobacteriaceae. Farms that administered doxycycline (2/11) had 100% (KF) and 90% (MK) resistance to tetracycline among the Enterobacteriaceae.

LF administered penicillin and cloxacillin prophylactics and had 67% penicillin-resistant and 100% cloxacillin-resistant *Staphylococcus aureus*. MK administered doxycycline prophylactic and had 100% tetracycline-resistant *Staphylococcus aureus*.

Chloramphenicol prophylaxis was not significantly related (0.375) to the prevalence of chloramphenicol-nonsusceptible Enterobacteriaceae. Doxycycline-prophylaxis was significantly related (0.001) to tetracycline-nonsusceptible isolates. Penicillin prophylaxis was not significantly related (0.492) to penicillin-nonsusceptible *Staphylococcus aureus*.

4. Discussion

The frequency of antibiotic prophylaxis and multidrug resistant bacteria were high among selected birds with 100 of 110 birds receiving antibiotics every 7 days or less and 77 (64%) of tested isolates being multidrug resistant bacteria. Antibiotics act to destroy all the targeted pathogens by administering an approved dose in a course of treatment. The nature of frequent prophylaxis is contrary to good practice in terms of antibiotic stewardship. This is because pathogens can adapt to low doses as well as sub-inhibitory concentrations of an antibiotic from the incomplete course and reproduce populations that are completely resistant (Duong, 2015; Bengtsson-Palme, Kristiansson & Larsson, 2017). Widespread and indiscriminate exposure to antibiotics is a known contributing factor to antibiotic resistance (Ryan, 2018). The use of antibiotics may also give rise to resistance of pathogens or normal flora to that antibiotic as well as to some or all antibiotics of the same class (Philips, 1983). Since more than 100 of the selected birds had been exposed to antibiotics for more than four weeks with some for as long as 32 weeks of life the probability of selecting antibiotic resistant bacteria may become greater over time.

Most of the birds were broilers which are more likely to end up being slaughtered from 3 to 6 months. This would increase their exposure time to antibiotics and further enhance the selection of resistant bacteria. Contact practices of slaughtering the birds may lead to exposure to these bacteria. Worthy of note is the fact that layers are kept for a longer time and thus will be exposed to the antibiotics for a relatively longer duration. This may significantly influence the selection of antibiotic resistant bacteria in the layers and are likely to be presented on the eggs on the market reaching consumers. These can possibly cause infections if poorly handled during processing. Infections with antibiotic resistant bacteria are difficult to treat hence are a public health threat.

The most predominant bacteria was *Escherichia coli*. *E. coli* are common in the gastrointestinal tract of poultry and most are nonpathogenic but about 10-15% are known to be opportunistic and pathogenic serotypes (Akond et al., 2009). Their presence and high occurrence is an indicator of the presence of enteric zoonotic bacteria and faster acquisition of antimicrobial resistance (Mwambate & Stephen, 2015; Shecho et al., 2017). Infections due to antibiotic resistant strains should be a major concern. Munang'andu, Kabilika, Chibomba, Munyeme & Muuka (2012) reported *Escherichia coli*, *Salmonella gallinarum* and *Proteus sp.* as the major bacteria species accounting for chick mortality. All three were found in this study with *Proteus sp.* being the next most predominant bacteria of the Enterobacteriaceae group after *E. coli.* Other predominant members in the group after *Proteus sp.* were *Citrobacter sp*., *Proteus vulgaris* and *Salmonella enterica*. Salmonella is known to be a serious human pathogen and its presence in meat and eggs is a major public health concern. *Citrobacter koseri*, *Klebsiella* and *Enterobacter sp*., and *Klebsiella oytoca* respectively also found in order of occurrence are all potential human pathogens that commonly cause infections. These may also be a reservoir of antibiotic resistance which can be passed on through mobile genes to pathogenic bacteria and cause treatment failure in cases of morbidity in both livestock and humans.

Staphylococci were the most predominant after *E. coli*. Siddiqui, Khan, Suradkar, Mendhe, Rindhe & Sirsat (2008) also reported *Staphylococci* as the most predominant bacteria isolated from different specimens from chicken after *E. coli*. The predominance of these bacteria may be representative of their presence in the gut of the birds from which these were isolated. In the era of Methicillin-resistance, antibiotic resistant Staphylococci are a major public health concern especially in this case where the commercial poultry farms, like in other parts of the country, are centered in the urban and peri-urban areas. Such dense human populations promotes transmission. Although MRSA test was not done in this study Bounar-Kechih, Hamdi, Aggad, Meggueni & Cantekin (2018) reported MRSA of 57% in layers and 50% in broilers in Northern Algeria. It is possible that there that there may be MRSA among the staphylococci in this study due to the high prevalence of multidrug resistant isolates that were detected. Further threat is the high occurrence of vancomycin-resistant *Staphylococcus aureus* (67%) since vancomycin is considered as the antibiotic of last resort for treating multidrug-resistant *Staphylococcus aureus* infections (Boneca & Chiosis, 2003). Otalu, Junaidu, Chukwudi & Jariath (2011) reported 46.1% vancomycin-resistant *S. aureus* from live and slaughtered poultry in Nigeria.

Gentamicin and ciprofloxacin were found to be effective against over 70% of Enterobacteriaceae and *Staphylococcus aureus* in this study. The high prevalence (>60%) of resistance to penicillin (81%), cloxacillin (100%) and tetracycline (85%) closely conformed to high prevalence of resistance at the two sites where these antibiotics were being administered as prophylactics. This may infer that generally there is a high prevalence of antibiotic resistant *Staphylococcus aureus* among the birds and the administration of these antibiotics as prophylactics may further increase the phenomenon. For instance, apart from staphylococci being known to be usually resistant to tetracycline, Scholar et al. (2017) has reported a decline in the general usefulness of tetracycline due to widespread resistance.

Although ampicillin and penicillin are in the same beta-lactam class, at sites where ampicillin prophylactic was administered the prevalence of ampicillin-resistant Enterobacteriaceae was low for site LF (15%) but high for site FV (78%) in spite of the fact that the latter had been on penicillin-prophylaxis for a lesser duration of 8-12 weeks compared to 8 to 16 weeks in the case of the former. Ampicillin is an effective drug against Gram negative bacteria hence the presence of ampicillin-resistant Enterobacteriaceae may be accounted for by beta-lactamase production which renders the antibiotic ineffective. Beta-lactam and other antibiotic resistance in Enterobacteriaceae have frequently been associated with plasmidic resistance determinants that are easily transferred among species (Bush, 2010).

There was a significant relationship between doxycycline-prophylaxis and carriage of tetracycline-nonsusceptible zoonotic bacteria. The specific use of doxycycline as a prophylactic may account for the high occurrence of tetracycline-resistant Enterobacteriaceae in the birds that were being administered the antibiotic. A high prevalence (71%) of cefotaxime-resistant Enterobacteriaceae were found although cefotaxime was not among the prophylactics being administered. It may be attributed to the acquisition of resistant genes through plasmids by means of bacterial conjugation and transduction (Shecho et al., 2017). The use of chloramphenicol-prophylaxis was relative to a low (<40%) to moderate (40-60%) occurrence of resistance among the Enterobacteriaceae (20%, 23% and 44%).

The use of penicillin-prophylaxis may have accounted for the high occurrence of *Staphylococcus aureus* resistant to cloxacillin (100%), ampicillin (89%) and penicillin (81%) since these are in the same class of antibiotics and cross-resistance is a possible occurrence. For poultry receiving doxycycline-prophylaxis the occurrence of tetracycline-resistant *Staphylococcus aureus* (100%) and Enterobacteriaceae (90% and 100%) were high. The two drugs are in the same class hence cross-resistance may occur (Munita & Arias, 2016).

5. Conclusions and Recommendations

5.1 Conclusion

This study reports a high cloacal carriage of multidrug resistant zoonotic bacteria in commercially-bred poultry probably due to the frequently administered antibiotic prophylactics. It has also established a significant relationship between doxycycline-prophylaxis and carriage of tetracycline-nonsusceptible zoonotic bacteria in the birds. The study also reports a high occurrence of vancomycin-resistant *Staphylococcus aureus*. Amikacin was the most effective antibiotic against Enterobacteriaceae whereas gentamicin and ciprofloxacin were effective against most Enterobacteriaceae and *Staphylococcus aureus*. To safeguard antibiotics for posterity and prevent the selection and development of resistant zoonotic bacteria, common antibiotics which remain clinically effective for treating infections in humans should not be used in poultry farming.

5.2 Recommendations

Regulations need to be enforced on which antibiotics are permitted for use in poultry farming activities, how these are used and when these are used. There should be adherence to the WHO statement on use of prophylactics in animal husbandry. This requires that prophylactic use of antibiotics for individual animals should be permitted when risk of disease is high and group treatments should be permitted only when there is no available treatment and there is a high risk of transmission to others. Vaccination, strict biosecurity, proper pen hygiene and sanitation coupled with measures such as the use of probiotics, prebiotics, enzymes and phytogenic feed alternatives should be used to reduce dependence on antibiotics in poultry farming. Until new and effective options are available these measures will ensure that the current line of effective antibiotics in the high-priority class are not abused through indiscriminate use by poultry farmers.

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