Characterization of antibiotic resistant *Escherichia coli* in different poultry farming systems in the Eastern Province and Kigali City of Rwanda

Rosine Manishimwe[1*] Martin Buhire[1] Alexie Uyisunze[1]
Jean Bosco Turikumwenayo[1] Michael Tukei[1]

Keywords

Poultry farming, resistance to antibiotics, public health, Rwanda

Submitted: 7 January 2016
Accepted: 9 August 2017
Published: 20 September 2017
DOI: 10.19182/remvt.31392

Summary

Antibiotic resistance has become a global public health concern as a wide number of resistant bacteria are continuously emerging. Animals have been pointed out as one of the sources of antibiotic-resistant bacteria that can be transferred to humans. To enrich the data on antibiotic resistance in animals in Rwanda, a cross-sectional study was carried out in the Eastern Province and in Kigali City to isolate *Escherichia coli* from free-range and commercial poultry farms. Fecal samples were collected from 294 poultry farms and *E. coli* strains were isolated and identified. In total 241 *E. coli* isolates were subjected to an antibiotic sensitivity test using five antibiotics (gentamicin, streptomycin, rifampicin, doxycycline and erythromycin). Antibiotic use in poultry was low in free-range poultry farms (30.9%) compared to layer and broiler production farms (100%). Among 151 farmers who reported using antibiotics in poultry, almost half (49.7%) always used antibiotics with a veterinarian prescription. Out of 241 *E. coli* isolates, 43.2% had a multiple resistance to four of the five antibiotics tested. Almost all the isolates (98.8%) were resistant to erythromycin, 78.8% were resistant to streptomycin, 77.6% were resistant to doxycycline, 69.3% were resistant to rifampicin and only a few were resistant to gentamicin (3.7%). No statistically significant difference was observed regarding isolate resistance against antibiotics according to the farming system type. However, resistance of isolates to doxycycline was significantly higher in farms where antibiotic use was reported (84%) than in farms where antibiotic use was not reported (70%). The observed antibiotic resistance of *E. coli* shows the existence of a potential source of resistance that can be transferred to pathogenic bacteria and impact humans as well as animals.

■ How to quote this article: Manishimwe R., Buhire M., Uyisunze A., Turikumwenayo J.B., Tukei M., 2017. Characterization of antibiotic resistant *Escherichia coli* in different poultry farming systems in the Eastern Province and Kigali City of Rwanda. *Rev. Elev. Med. Vet. Pays Trop.*, **70** (1): 13-19, doi: 10.19182/remvt.31392

■ INTRODUCTION

The sector of poultry production continues to grow and to be more industrialized in many parts of the world. The amount of chicken meat produced per year has been increasing worldwide for the last decade (FAOSTAT, 2017). An increasing human population, greater purchasing power and urbanization have been strong drivers of this growth (FAO, 2016). Moreover, commercial poultry farms play an important role in meeting the protein supply through the supply of eggs and meat (Jabir and Hague, 2010). Rwanda is a small landlocked country of a geographical area of 26,338 square kilometers and about 12 million inhabitants (NISR, 2016). To alleviate poverty and ensure sustainable food security, the efficient use of the available land through poultry and small livestock production could be one of the options (Mbuza et al., 2016). In this regard, one of the options for emphasis by the government of Rwanda was to promulgate a policy that promotes the increase in animal protein production by encouraging pig, poultry and other small animal productions (MINAGRI, 2012). The poultry industry has been developing quickly in the country, mainly in the Eastern Province with a rise in commercial poultry farms in Kigali City. This may imply a widespread use of antibiotics in poultry productions to control and prevent bacterial diseases but

1. School of Animal Sciences and Veterinary Medicine, University of Rwanda, Nyagatare Campus, Rwanda.

* Corresponding author
Tel.: +250 7875031119; Email: rosinem3@yahoo.fr

also to promote growth in poultry (Manishimwe et al., 2015). Unfortunately, since the use of antibiotics in animals is poorly regulated in Rwanda (Ndayisenga, 2009) and poultry farmers lack trainings on animal health management (Mbuza et al., 2016; Mbuza et al., 2017), antibiotic resistance could emerge from poultry farms.

Normal intestinal flora of animals constitutes an enormous reservoir of resistance genes that can be transferred to pathogenic bacteria (Carlet, 2012). The emergence of resistant bacteria in the gut may be an indicator for selection pressure exerted by antibiotic use in each animal population (Carlet, 2012). In Rwanda, studies on antibiotic resistance in poultry (Omulo et al., 2015) are scarce. But in other African countries, several studies have established the prevalence of resistant *E. coli* strains in poultry farms (Kikuvi et al., 2006; Majalija et al., 2010; Naliaka, 2011; Hamisi et al., 2012; Alonso et al., 2017). Other studies showed differences in the antibiotic resistance of *E. coli* between various farming systems (Okoli, 2006; Naliaka, 2011; Rugumisa et al., 2016). Investigations of antibiotic resistance of *E. coli* are useful to identify types of resistance present in the region and better understand the challenge to establish appropriate and effective interventions (Omulo et al., 2015). Unfortunately, in Rwanda, little is known on the extent of antibiotic resistant strains of *E. coli* in poultry farms, hence the risk of antibiotic resistance spreading from poultry to humans or other animals cannot be estimated. This baseline study aimed at investigating the distribution of antibiotic resistant strains of *E. coli* isolated from different poultry farming systems in the Eastern Province and Kigali City in Rwanda.

■ MATERIALS AND METHODS

Study area and sampling method

A cross-sectional study was conducted from April to September 2015 in two areas of Rwanda, the Eastern Province and Kigali City. As a baseline study, poultry farms were randomly selected from only two provinces out the five provinces in the country.

Two types of farming systems were targeted for data collection:
– The free-range farming system where poultry are reared for eggs and meat and no special investments are made for the poultry production.
– The commercial farming systems where poultry are reared in an intensive system for meat (broilers) or eggs (layers) and investments are made for the production.

Our hypothesis was that antibiotic resistance would be high in commercial farms.

Sample collection

Using a sterile plastic spatula, one sample of fresh feces was collected from each selected farm and put in a 30 ml sterile container. The fecal sample was made of a mixture of 5 fresh droppings collected randomly and aseptically from poultry pens (commercial farms) or from the poultry-feeding ground (free-range farms). Using a form, information on the farm regarding the location, the use of antibiotics and the rearing system were directly recorded. The collected fecal samples were maintained on ice and transported to the laboratory of veterinary medicine, University of Rwanda, in the Eastern Province, 160 kilometers away from Kigali City. The maximum duration of sample transportation from the study area to the laboratory was four hours and samples were processed the same day.

Isolation and identification of Escherichia coli

In the laboratory, 1 g of fecal samples was inoculated into 9 ml of peptone water (QUELAB, Quebec, Canada) and incubated at 37 ºC for 18 h. Subsequently, the cultures were streaked on Mac Conkey agar (HIMEDIA, Mumbai, India) and incubated overnight at 37 ºC. One of the lactose fermenting colonies per sample was randomly selected and streaked on eosin methylene blue (EMB) agar (OXOID, Hampshire, England) and incubated overnight at 37 ºC. Colonies that showed growth characteristics of *E. coli* (metallic green sheen colonies) were randomly selected and subjected to IMVC tests (indole, methyl red, Voges-Proskauer reaction and Simon's citrate) for identification of *E. coli* isolates. One confirmed *E. coli* colony per sample was randomly selected for antibiotic sensitivity testing. Selected *E. coli* isolates for sensitivity testing were streaked onto blood agar (HIMEDIA), incubated overnight and subjected to sensitivity tests the following day.

Antimicrobial susceptibility testing

Antimicrobial sensitivity testing was carried with the disk diffusion method on Mueller-Hinton agar (TMAST, Merseyside) according to the recommendations reported by the Clinical and Laboratory Standards Institute (CLSI, 2013). Five antimicrobial agent disks (LIOFILCHEM, Italy) were selected because they are commonly used to treat bacterial diseases in both humans and animals. The used antibiotics were gentamicin (10 μg), streptomycin (10 μg), doxycycline (30 μg), erythromycin (15 μg) and rifampicin (30 μg). After inoculation by *E. coli* isolates and antibiotic disks' placement, Muller-Hinton agar plates were incubated at 37 °C for 18 h. After incubation, the inhibition zones were measured using calipers to the nearest millimeter and interpreted as susceptible, intermediate and resistant (CLSI, 2013). *E. coli* ATCC 25922 was used as a reference strain for quality control of antibiotic sensitivity testing.

Statistical analyses

Data were entered with EpiData 3.1. software. Statistical analyses were performed with SPSS version 16. The prevalence of antibiotic resistance among different groups was calculated by dividing the number of resistant isolates in the group to the number of *E. coli* isolates in the group. Chi-square tests were used for statistical analyses. The adjustment of p values for multiple comparison was performed with Bonferroni correction. A difference was considered as significant if p was inferior to 0.05.

■ RESULTS

Sample description

During this study we visited 294 poultry keepers. Most of them were free-range poultry keepers (70.4%), others were layer poultry keepers (26.5%) and the remaining were boiler poultry keepers (3.2%). Most of visited farms were in the Eastern Province (73.8%) (Table I).

Table I

Number of visited poultry farms by farming system and farm location in the Eastern Province and Kigali City in Rwanda

Farming system	Eastern Province	Kigali City	Total
Broiler	3	6	9
Free range	168	39	207
Layer	46	32	78
Total	217	77	294

Antibiotic use in poultry

About half of respondents (51.4%) reported to use antibiotics in their poultry, whereas the rest (48.6%) reported having never used antibiotics in their poultry. All poultry keepers rearing broilers or layers declared using antibiotics in their poultry, whereas only 30.9% of free-range poultry keepers declared using them. Among the 151 respondents who used antibiotics, 33.8% stated that it was for both infection treatment and prevention. Additionally, among these 151 poultry keepers, 49.7% reported that they always sought advice from a veterinarian before using an antibiotic in poultry. Reasons of antibiotic use in poultry were statistically different according to the poultry farming system ($p = 0.000$). We noted that 77.8% of the broiler, 73.1% of the layer and only 17.2% of the free-range keepers always sought veterinary advice before using antibiotics in their poultry. The consistency for a farmer to consult a veterinarian before antibiotic use in poultry was statistically different depending on the farming system ($p = 0.000$) (Table II).

Bacterial isolates and antibiotic susceptibility testing

E. coli strains were isolated from 82% of the samples, of which 79.7% originated from free-range farms, 88.5% from layer farms, and 77.8% from broiler farms (Table III). All *E. coli* isolates were tested for their sensitivity to five antibiotics. We observed that 3.3% of *E. coli* isolates showed a multiple resistance to all antibiotics tested, and only one isolate (0.4%) was susceptible to all antibiotics (Table IV). In addition, 43.2% of *E. coli* isolates had a multiple resistance to four antibiotics. Compared to other antibiotics, we detected a low resistance of *E. coli* isolates to gentamicin (3.7%) and a high resistance (98.8%) to erythromycin (Table V). No statistically significant difference was noticed between resistance of isolates to the five antibiotics according to the farming systems. However, we noticed that resistance of isolates to doxycycline was significantly higher (84%) in farms where antibiotics were used in poultry than in farms where antibiotics were not used in poultry (70%) ($p < 0.01$) (Table VI).

Table III

Number of *Escherichia* isolates by farming system and use of antibiotics in poultry in the Eastern Province and Kigali City in Rwanda

	Num. of visited farms	Num. of isolates	%
Farming system			
Broiler	9	7	77.8
Free range	207	165	79.7
Layer	78	69	88.5
Use antibiotics			
Yes	151	131	86.8
No	143	110	76.9
Total	294	241	82.0

Table IV

Number of *Escherichia* isolates resistant to multiple antibiotics (ant.) from poultry farms in the Eastern Province and Kigali City in Rwanda

	Num. of isolates	%
Resistant to 1 ant.	9	3.7
Resistant to 2 ant.	31	12.9
Resistant to 3 ant.	88	36.5
Resistant to 4 ant.	104	43.2
Resistant to 5 ant.	8	3.3
Susceptible to all ant.	1	0.4
Total	241	100

Table II

Number of poultry keepers using antibiotics in poultry production in the Eastern Province and Kigali City in Rwanda

	Broiler		Free range		Layer		Total	%
	N	%	N	%	N	%		
Use of antibiotics								
Yes	9	100	64	30.9	78	100	151	51.4
No	0	0	143	69.1	0	0.0	143	48.6
Total	9	100	207	100	78	100	294	100
Purpose of antibiotic use								
Prevention	1^{ab}	11.1	2^{a}	3.1	29^{b}	37.2	32	21.2
Treatment and prevention	7^{a}	77.8	5^{b}	7.8	39^{a}	50	51	33.8
Treatment	1^{a}	11.1	57^{b}	89.1	10^{a}	12.8	68	45.0
Total	9	100	64	100	78	100	151	100
Veterinary advice before use								
Always	7^{a}	77.8	11^{b}	17.2	57	73.1	75	49.7
Never	0	0	27^{a}	42.2	5^{b}	6.4	32	21.2
Sometimes	2^{ab}	22.2	26^{a}	40.6	16^{b}	20.5	44	29.1
Total	9	100	64	100	78	100	151	100

* Values in the same row with different subscripts are significantly different at $p < 0.05$ in the two-sided test of equality for column proportions. Values without subscripts are not included in the test.

TableV

Prevalence of antibiotic resistance profiles among *Escherichia* isolates (n = 241) from poultry farms in the Eastern Province and Kigali City in Rwanda

Antibiotics	Resistant		Intermediate		Sensitive	
	Num. of isolates	%	Num. of isolates	%	Num. of isolates	%
Gentamicin	9	3.7	17	7.1	215	89.2
Rifampicin	167	69.3	71	29.5	3	1.2
Doxycycline	187	77.6	50	20.7	4	1.7
Streptomycin	190	78.8	28	11.6	23	9.5
Erythromycin	238	98.8	3	1.2	0	0.0

Table VI

Prevalence of resistant *Escherichia coli* isolates according to the poultry farming systems and the antibiotic (ant.) in the Eastern Province and Kigali City in Rwanda

		Rearing system						Antibiotic use in poultry			
		Free range		Broiler		Layer		No		Yes	
		N	%	N	%	N	%	N	%	N	%
Erythromycin	Resistant isolates	163[a]	98.8	7	100	68[a]	98.6	108[a]	98.2	130[a]	99.2
Gentamicin	Resistant isolates	5[a]	3.0	0	0.0	4[a]	5.8	2[a]	1.8	7[a]	5.3
Streptomycin	Resistant isolates	131[a]	79.4	7	100	52[a]	75.4	84[a]	76.4	106[a]	80.9
Doxycycline	Resistant isolates	125[a]	75.8	5[a]	71.4	57[a]	82.6	77[a]	70.0	110[b]	84.0
Rifampicin	Resistant isolates	119[a]	72.1	5[a]	71.4	43[a]	62.3	80[a]	72.7	87[a]	66.4
Multiple antibiotic resistance	Resistant to 1 ant.	4[a]	2.4	0	0.0	5[a]	7.2	3[a]	2.7	6[a]	4.6
	Resistant to 2 ant.	20[a]	12.1	1[a]	14.3	10[a]	14.5	16[a]	14.5	15[a]	11.5
	Resistant to 3 ant.	66[a]	40.0	2[a]	28.6	20[a]	29.0	46[a]	41.8	42[a]	32.1
	Resistant to 4 ant.	69[a]	41.8	4[a]	57.1	31[a]	44.9	42[a]	38.2	62[a]	47.3
	Resistant to 5 ant.	5[a]	3.0	0	0.0	3[a]	4.3	2[a]	1.8	6[a]	4.6
	Susceptible to all ant.	1[a]	0.6	0	0.0	0	0.0	1[a]	0.9	0	0.0
Num. of *E. coli* isolates		165		7		69		110		131	

* Values in the same row with different subscripts are significantly different at $p < 0.05$ in the two-sided test of equality for column proportions. Values without subscripts are not included in the test

■ DISCUSSION

Antibiotic use in food animals is highly increasing in many parts of the world (Van Boeckel et al., 2015). Unfortunately, irrational use of antibiotics in animals has been linked with antibiotic-resistant bacterial strains (Miles et al., 2006; Bonnet et al., 2009). These antimicrobial resistant strains are not only a limitation to successful animal production operations but also constitute a serious public health threat.

It has been shown that antimicrobial resistance can be transmitted from animals to humans, leading to infections that are difficult to treat (Economou and Gousia, 2015). The focus of this study was to investigate the prevalence of antimicrobial resistant *E. coli* and to assess the use of antimicrobials in poultry farms in the Eastern Province and Kigali City of Rwanda.

We noticed that the use of antibiotics in poultry was a common practice in more than half of the respondents. In 50.3% of the visited farms, antibiotics were not always used in poultry with veterinarian prescriptions, and in 55% of farms, antibiotics were used not only for treatment purposes but also for disease prevention. These irrational practices are known to lead to selection of antimicrobial resistant bacteria (McEwen and Fedorka-Cray, 2002; Marshall and Levy, 2011). Most of the farmers using antibiotics in poultry for disease prevention were from commercial farming systems (layer and broiler productions). This can be attributed to the fact that farmers owning commercial poultry productions may prioritize benefit, and they may use antibiotics not only as a preventive method to minimize poultry losses due to bacterial infections but also to boost the growth of their chickens.

On the other hand, most farmers using antibiotics in poultry without a veterinarian prescription were from free-range farming system. This can be linked to their low income that does not enable them to pay for veterinary services. Besides, farmers in the free-range systems are known to lack adequate skills and knowledge in poultry health management.

High prevalence rates of antimicrobial resistant *E. coli* isolates were observed in the Eastern Province and Kigali City of Rwanda. The

Revue d'élevage et de médecine vétérinaire des pays tropicaux, 2017, 70 (1) : 13-19

general observation was that *E. coli* isolates from the visited poultry farms were highly resistant to most of the antibiotics tested, with a high resistance to erythromycin (98.8%) and a low resistance to gentamicin (3.7%). We also observed that 43.2% of isolates were resistant to four of the five antibiotics tested for sensitivity.

The challenge is not negligible as four of the antibiotics tested in this study are classified by WHO (2011) as extremely important antibiotics in human medicine, and the other one is classified as a highly important antibiotic. The presence of antibiotic resistant *E. coli* isolates in poultry farms has also been documented in different African countries (Kikuvi et al., 2006; Majalija et al., 2010; Naliaka, 2011; Hamisi et al., 2012; Zeryehun and Bedada, 2013; Mshana et al., 2013; Rugumisa et al., 2016).

We observed no statistically significant difference in antibiotic resistance levels between different poultry farming systems. A similar observation was made by Naliaka (2011) who reported identical rates of multiple antibiotic resistance in different poultry farming systems in Kenya. On the contrary, in Tanzania, a clear difference of resistance to different antibiotics was noted between free-range poultry farms and commercial layer farms (Rugumisa et al., 2016). The findings of this study can be explained by the possibility that poultry in the visited free-range farms might be exposed to populations of resistant bacteria in the environment (Wellington et al., 2013). A transmission of resistant strains from commercial to free-range poultry farms may be another explanation. In addition, in Rwanda, many of the households that own poultry in a free-range system practice mixed livestock breeding (Hetherington et al., 2017), enabling eventual cross-contamination and transfer of antimicrobial resistance between different animal species.

Although the poultry industry is rapidly evolving in Rwanda as in other East African countries, knowledge and skills related to biosafety management in poultry production are still low among farmers (Omulo et al., 2015; Mbuza et al., 2016; Mbuza et al., 2017). We noticed that resistance of *E. coli* isolates to doxycycline was significantly higher in the farms which used antibiotics for their poultry than in those which did not use them. This may be seen as an indicator for irrational use of antibiotics among poultry farmers that can lead to the emergence of antibiotic resistance.

The resistance detected in *E. coli* isolates from poultry in this study may have been caused by the selection pressure due to antibiotic use in poultry (McEwen and Fedorka-Cray, 2002). The quality of antibiotics used in poultry could be another factor for the emergence of antibiotic resistance (Okeke and Ojo, 2010). A study conducted by Ndayisenga (2009) revealed that a non-negligible percentage of antibiotics, such as oxytetracycline used in animals in Rwanda, did not meet the standards claimed on their labels. Some antibiotics were under dosed and others were overdosed in active ingredients. Trade growth and population movements in the country may also increase the speed and facility with which resistant microorganisms can spread between different regions (Byarugaba, 2004). Of further concern, resistant organisms often carry resistance genes that can be transmitted to other pathogens and therefore constitute a hidden reservoir of antibiotic resistance (Straand et al., 2008).

From the findings of this study we can deduce a high risk of farmers' contamination by antimicrobial resistant bacteria of poultry origin, and their spread to the general population. Similarly, the risk of producing contaminated poultry products and the risk of dissemination of resistant bacteria to other animals are equally high.

■ CONCLUSION

This is the first study in Rwanda to avail information on antibiotic resistance of *E. coli* isolated from different poultry farming systems. The prevalence of *E. coli* isolates resistant to the antibiotics tested was generally high (greater than 65%) except for gentamicin (less than 5%). We observed no statistically significant difference of antibiotic resistance between the different poultry farming systems. On the other hand, we noticed some irrational antibiotic use practices among poultry farmers. Despite its limitations, especially the scarcity of information on antibiotic use practices and the low number of antimicrobials tested, this study showed that the antimicrobial resistance in the poultry industry in Rwanda is a serious problem. For this reason, one-health-based large-scale studies on antimicrobial resistance at molecular level in all animal production systems and humans are necessary. These would help assess the extent of the threat posed by antimicrobial resistance and search for responses.

We also recommend that policies and regulations promoting rational use of antibiotics should be established and enforced in Rwanda. The World Organisation for Animal Health (OIE, 2016) provides guidance toward a responsible and prudent use of antimicrobial agents in veterinary medicine. This guidance can be used as a baseline to establish contextualized policies and regulations controlling the import, the distribution and the utilization of antibiotics used in animals and specifically in poultry production in Rwanda.

Acknowledgments

We wish to acknowledge Tufts-Cummings for the financial support of this study. We also acknowledge Dr. Caroline Ryan, Dr. Jennifer Steel, Prof. Diane, Dr. Amuguni Hellen, Maurice Byukusenge and Kizito Nishimwe for their inputs and advice. Great thanks are extended to poultry keepers who voluntarily participated in this study.

REFERENCES

Alonso C.A., Zarazaga M., Ben Sallem R., Jouini A., Ben Slama K., Torres C., 2017. Antibiotic resistance in *Escherichia coli* in husbandry animals. The African perspective. *Lett. Appl. Microbiol.*, **64** (5): 318-334, doi: 10.1111/lam.12724

Bonnet C., Diarrassouba F., Brousseau R., Masson L., Topp E., Diarr M.S., 2009. Pathotype and antibiotic resistance gene distribution of *Escherichia coli* isolates from broiler chickens raised on antimicrobial supplemented diets. *Appl. Environ. Microbiol.,* **75** (22): 6955-6962, doi:10.1128/AEM.00375-09

Byarugaba D., 2004. Antimicrobial resistance in developing countries and responsible risk factors. *Int. J. Antimicrob. Agents,* **24** (2): 105-110, doi: 10.1016/j.ijantimicag.2004.02.015

Carlet J., 2012. The gut is the epicentre of antibiotic resistance. *Antimicrob. Resist. Infect Control,* **1** (1): 39, doi: 10.1186/2047-2994-1-39

Clinical and Laboratory Standard Institute, 2013. Performance standards for antimicrobial susceptibility testing. https://clsi.org/

Economou V., Gousia P., 2015. Agriculture and food animals as a source of antimicrobial-resistant bacteria. *Infect. Drug Resist.,* **8**: 49-61, doi: 10.2147/IDR.S55778

FAO, 2016. Poultry and... www.fao.org/ag/againfo/themes/en/poultry/home.html (accessed 16 March 2017)

FAOSTAT, 2017. Livestock production, poultry meat production, www.fao.org/faostat/en/#data/QL (accessed 14 March 2017)

Hamisi Z., Tuntufye H., Shahada F., 2012. Antimicrobial resistance phenotypes of *Escherichia coli* isolated from tropical free range chickens. *Int. J. Sci. Res.,* **3** (9): 2319-7064

Hetherington J.B., Wiethoelter A.K., Negin J., Mor S.M., 2017. Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agric. Food Security*, **6** (9), doi: 10.1186/s40066-016-0079-z

Jabir F., Hague M.T., 2010. Study on production performance of ISA Brown strain at Krishibid Firm Ltd. Trishal, Mymensingh. *Bangladesh Res. Publ. J.*, **3** (3): 1039-1044

Kikuvi G.M., Ole-Mapenay I.M., Mitema E.S., Ombui J.N., 2006. Antimicrobial resistance in *Escherichia coli* isolates from faeces and carcass samples of slaughter cattle, swine and chickens in Kenya. *Israel J. Vet. Med*., **61** (3-4): 82-88

Majalija S., Oweka F., Wito G.S., Musisi-Lubowa, Vudriko P., Nakamya F.M., 2010. Antibiotic susceptibility of fecal *Escherchia coli* isolates from dip-litter broiler chickens in Northern and central Uganda. *J. Vet. Res.*, **3** (4): 75-80

Manishimwe R., Zeynudin A., Musafiri S., Mushayija J.P., Mushimiyimana K., Umuhire O., Nshimirimana E., Mdegela R., 2015. Knowledge, attitudes and practices regarding antibiotics, their use and resistance among the public community in Rwanda. In: Second One-Health International conference, Kampala, Uganda, 16-18 Nov. 2015

Marshall B.M., Levy S.B., 2011. Food animals and antimicrobials: Impacts on human health. *Clin. Microbiol. Rev.,* **24** (4): 718-733, doi: 10.1128/CMR.00002-11

Mbuza F., Habimana R., Simbankabo T., Majyambere D., 2016. Characterization of layer poultry production in Rwanda. *Int. J. Agric. Sci*., **6**: 1148-1156

Mbuza F., Manishimwe R., Mahoro J., Nishimwe K., 2017. Characterization of broiler poultry production system in Rwanda. *Trop. Anim. Health Prod.,* **49**: 71, doi: 10.1007/S11250-016-1160-0

McEwen S.A., Fedorka-Cray P.J., 2002. Antimicrobial use and resistance in animals. *Clin. Infect. Dis.*, **34** (3): 93-106, doi: 10.1086/340246

Miles T.D., McLaughlin W., Brown P.D., 2006. Antimicrobial resistance of *E. coli* from broiler chickens and humans. *BMC Vet. Res*., **6**: 2-7, doi: 10.1186/1746-6148-2-7

MINAGRI, 2012. Strategic and investment plan to strengthen the poultry industry in Rwanda. MINAGRI, Kigali, Rwanda www.minagri.gov.rw/fileadmin/user_upload/documents/STRAT.PLC/POULTRY_INDUSTRY_IN_RWANDA_Final.pdf (accessed 7 February, 2017)

Mshana S.E., Matee M., Rweyemamu M., 2013. Antimicrobial resistance in human and animal pathogens in Zambia, Democratic Republic of Congo, Mozambique and Tanzania: an urgent need of a sustainable surveillance system. *Ann. Clin. Microbiol. Antimicrob*., **12**: 28, doi: 10.1186/1476-0711-12-28

Naliaka M.A., 2011. A comparative study of antibiotic resistance profiles among enteric bacteria in broilers and traditional chicken from selected farms in Kericho, Kenya. MSc Thesis, Kenyatta University, Nairobi, Kenya

Ndayisenga F., 2009. Analysis of the distribution and quality of veterinary drugs in Rwanda. Vet. Doct. Thesis, Ecole inter-Etats des sciences et médecine vétérinaires, Université Cheikh Anta Diop, Dakar, Sénégal

NISR, 2016. Statistical yearbook, Rwanda. National Institute of Statistics of Rwanda. www.statistics.gov.rw/publication/statistical-yearbook-2016 (accessed 25 February 2017)

OIE, 2016. Terrestrial animal health code. OIE, Paris, France. www.oie.int/index.php?id=169&L=0&htmfile=chapitre_antibio_use.htm (accessed 10 March 2017)

Okeke I.N., Ojo K.K., 2010. Antimicrobial use and resistance in Africa. In: Antibiotic resistance in developing country (Eds de J. Sosa A., Byarugaba D.K., Amábile-Cuevas C.F., Po-Ren Hsueh, Kariuki S., Okeke I.N.). Springer, 301-314, doi: 10.1007/978-0-387-89370-9_17

Okoli I.C., 2006. Anti-microbial resistance profiles of *E. coli* isolated from free-range chickens in urban and rural environments of Imo State, Nigeria. *Online J. Health Allied Sci*., **1**: 3

Omulo S., Thumbi S.M., Njenga M.K., Call D.R., 2015. A review of 40 years of enteric antimicrobial resistance research in Eastern Africa: What can be done better? *Antimicrob. Resist. Infect. Control,* **4** (1): 1-13, doi: 10.1186/s13756-014-0041-4

Rugumisa B.T., Call D.R., Mwanyika G.O., Subbiah M., Buza J., 2016. Comparison of the prevalence of antibiotic-resistant *Escherichia coli* isolates from commercial-layer and free-range chickens in Arusha district, Tanzania. *Afr. J. Microbiol. Res*., **10** (34): 1422-1429, doi: 10.5897/AJMR2016.8251

Straand J., Gradmann C., Lindbæk M., Simonsen G.S., 2008. Antibiotic development and resistance. In: International Encyclopedia of Public Health, 2nd edition (Eds. Quah S.R.) Academic Press, MA, USA, p. 129-139, doi: 10.1016/B978-012373960-5.00367-1

Van Boeckel T.P., Brower C., Gilbert M., Grenfell B.T., Levin S.A., Robinson T.P., Laxminarayan R., 2015. Global trends in antimicrobial use in food animals. *Proc. Nat. Acad. Sci.,* **112** (18): 5649-5654, doi: doi:10.1073/pnas.1503141112

Wellington E.M.H., Boxall A.B.A., Cross P., Feil E.J., Gaze W.H., Hawkey P.M., Johnson-Rollings A.S., Jones D.L., Lee N.M., Otten W., 2013. The role of the natural environment in the emergence of antibiotic resistance in gram-negative bacteria. *Lancet Infect. Dis.,***13**: 155-165, doi: http://dx.doi.org/10.1016/S1473-3099(12)70317-1

WHO, 2011. Critically important antimicrobials for human medicine, 3rd Revision. World Health Organization, Geneva, Switzerland

Zeryehun T., Bedada B., 2013. Antimicrobial resistant pattern of fecal *Escherichia coli* in selected broiler farms of Eastern Hararge zone, Ethiopia. *Int. J. Appl. Biol. Pharm.,* **4** (1): 189-194

Résumé

Manishimwe R., Buhire M., Uyisunze A., Turikumwenayo J.B., Tukei M. Caractérisation d'*Escherichia coli* résistant aux antibiotiques dans différents systèmes avicoles de la province de l'Est et de la ville de Kigali au Rwanda

La résistance aux antibiotiques est devenue une préoccupation de santé publique mondiale car un grand nombre de bactéries résistantes émergent continuellement. Les animaux ont été signalés comme l'une des sources de bactéries résistantes aux antibiotiques qui peuvent être transférées aux humains. Afin d'enrichir les données sur la résistance aux antibiotiques chez les animaux au Rwanda, une étude transversale a été menée dans la province de l'Est et dans la ville de Kigali pour isoler *Escherichia coli* présent dans des élevages de volailles en plein air et dans des élevages commerciaux. Des échantillons de matières fécales ont été prélevés dans 294 fermes avicoles et des souches d'*E. coli* ont été isolées et identifiées. Au total, 241 isolats d'*E. coli* ont été soumis à un test de sensibilité aux antibiotiques en utilisant cinq antibiotiques (gentamicine, streptomycine, rifampicine, doxycycline et érythromycine). L'utilisation d'antibiotiques chez les volailles était faible dans les élevages de volaille en plein air (30,9 %) comparativement aux élevages de poules pondeuses et de poulets de chair (100 %). Parmi les 151 éleveurs qui ont déclaré utiliser des antibiotiques chez les volailles, près de la moitié (49,7 %) ont toujours utilisé des antibiotiques sur ordonnance vétérinaire. Sur les 241 isolats d'*E. coli*, 43,2 % présentaient une résistance multiple à quatre des cinq antibiotiques testés. Presque tous les isolats (98,8 %) étaient résistants à l'érythromycine, 78,8 % étaient résistants à la streptomycine, 77,6 % étaient résistants à la doxycycline, 69,3 % étaient résistants à la rifampicine et quelques-uns seulement étaient résistants à la gentamicine (3,7 %). Aucune différence significative statistiquement n'a été observée en ce qui concerne la résistance des isolats aux antibiotiques selon le type de système d'élevage. Toutefois, la résistance des isolats à la doxycycline a été significativement plus élevée dans les fermes où l'utilisation d'antibiotiques a été signalée (84 %) que dans les fermes où l'utilisation d'antibiotiques n'a pas été signalée (70 %). La résistance aux antibiotiques d'*E. coli* observée montre l'existence d'une source potentielle de résistance qui peut être transférée aux bactéries pathogènes et avoir un impact sur les humains et les animaux.

Mots-clés : élevage de volailles, résistance aux antibiotiques, santé publique, Rwanda

Resumen

Manishimwe R., Buhire M., Uyisunze A., Turikumwenayo J.B., Tukei M. Caracterización de *Escherichia coli* resistente a los antibióticos en diferentes sistemas avícolas de la provincia oriental y la ciudad de Kigali (Rwanda)

La resistencia a los antibióticos se ha convertido en una preocupación para la salud pública mundial, ya que un gran número de bacterias resistentes están emergiendo continuamente. Se ha señalado a los animales como una de las fuentes de bacterias resistentes a los antibióticos que pueden ser transferidas a los humanos. Para enriquecer los datos sobre la resistencia a los antibióticos en animales en Rwanda, se llevó a cabo un estudio transversal en la provincia oriental y en la ciudad de Kigali para aislar *Escherichia coli* de granjas avícolas comerciales y de cría al aire libre. Se recolectaron muestras fecales de 294 granjas avícolas y se aislaron e identificaron cepas de *E. coli*. En total, 241 aislados de *E. coli* fueron sometidos a una prueba de sensibilidad a los antibióticos utilizando cinco antibióticos (gentamicina, estreptomicina, rifampicina, doxiciclina y eritromicina). El uso de antibióticos en las aves de corral fue bajo en cría al aire libre (30,9%) en comparación con las granjas de producción de gallinas ponedoras y pollos de engorde (100%). Entre los 151 granjeros que informaron haber usado antibióticos en aves de corral, casi la mitad (49,7%) siempre usaron antibióticos con receta veterinaria. De las 241 cepas aisladas de *E. coli*, 43,2% tenía una resistencia múltiple a cuatro de los cinco antibióticos analizados. Casi todos los aislados (98,8%) eran resistentes a la eritromicina, 78,8% eran resistentes a la estreptomicina, 77,6% eran resistentes a la doxiciclina, 69,3% eran resistentes a la rifampicina y sólo unos pocos eran resistentes a la gentamicina (3,7%). No se observaron diferencias estadísticamente significativas con respecto a la resistencia de los aislamientos contra los antibióticos según el tipo de sistema de cría. Sin embargo, la resistencia de las cepas aisladas a la doxiciclina fue significativamente mayor en las granjas donde se informó del uso de antibióticos (84%) que en las granjas donde no se informó del uso de antibióticos (70%). La resistencia antibiótica observada de *E. coli* muestra la existencia de una fuente potencial de resistencia que puede ser transferida a las bacterias patógenas e impactar tanto en humanos como en animales.

Palabras clave: cría de aves de corral, resistencia a los antibióticos, salud pública, Rwanda