Antimicrobial Sales in Nairobi’s Peri-Urban Poultry Farming: Insights from ICT monitoring and Agrovet interviews

Linnea Lindfors

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Swedish University of Agricultural Sciences, SLU
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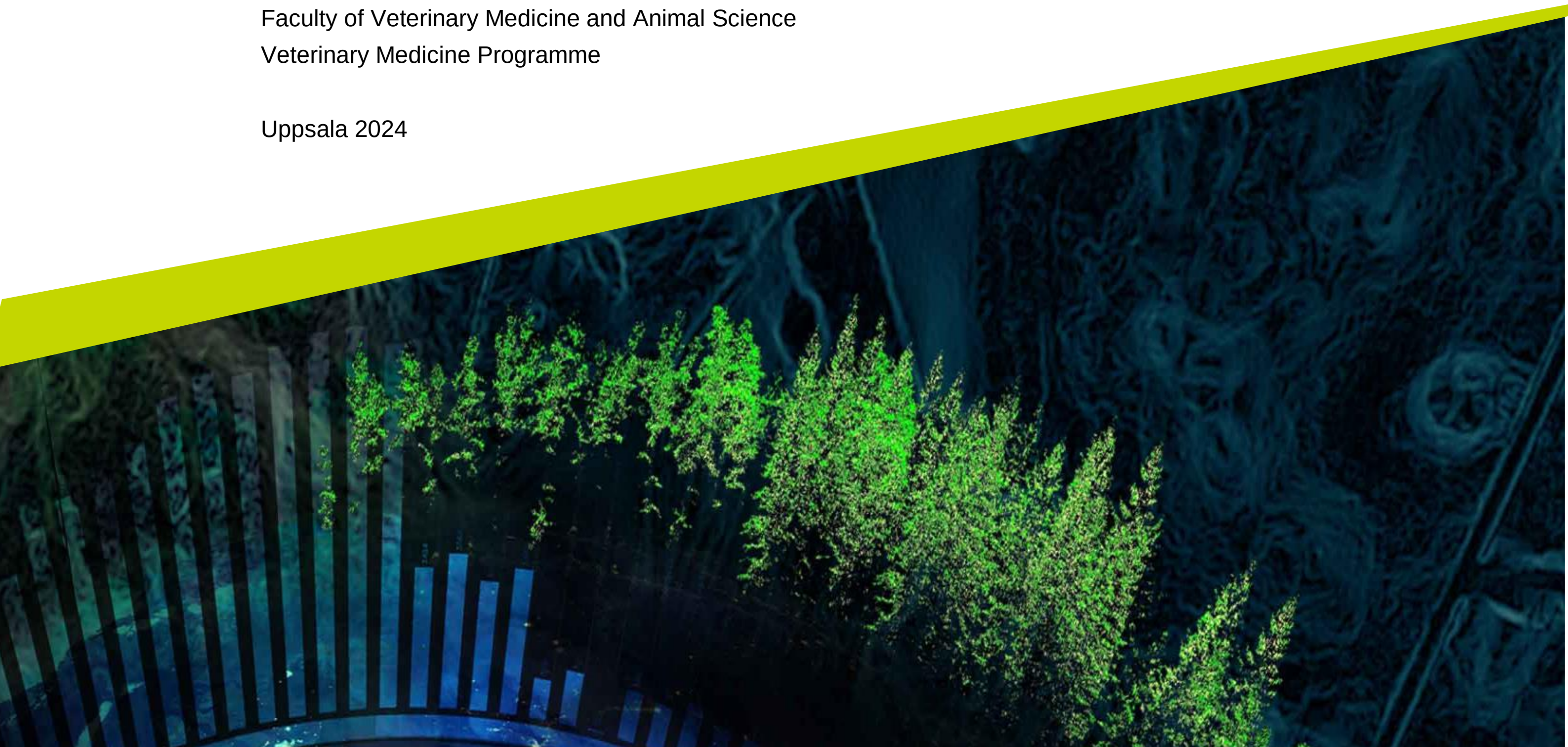

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Linnea Lindfors

Supervisor:	**Susanna Sternberg Lewerin, Swedish University of Agricultural Sciences (SLU), Department of Biomedicine and Veterinary Public Health**
Assistant supervisor:	Florence Mutua, International Livestock Institute (ILRI), Epidemiology
Examiner:	Sofia Boqvist, Swedish University of Agricultural Sciences (SLU), Department of Biomedicine and Veterinary Public Health

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Swedish University of Agricultural Sciences
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Abstract

The antimicrobial drug market in Kenya is currently unregulated, and there is a lack of knowledge regarding the extent of antimicrobial use in peri-urban poultry farming. The overuse of antimicrobials, particularly antibiotics, is driving antimicrobial resistance, posing a global threat. An Information and Communication Technology (ICT) application was introduced among selected agrovets in Kajiado and Machakos counties in Kenya to track antimicrobial sales. The sales data from three months were then analysed.

64% of the purchases contained antibiotics, with 68% of these composed of multiple antibiotic classes. Oxytetracycline and tylosin in combination with doxycycline was the most utilized antibiotics. All substances in the ten most common antibiotic purchases are classified as highly or critically important for human medicine by the WHO. The most common reference for a purchase was a new prescription (33%), followed by no reference (31%). In 34% of the purchases, a specific product was requested.

Interviews about the ICT program were conducted in each county, with a total of 12 agrovets attending. The recording of their sales impacted their awareness of antibiotic usage and provided them with new insights. The biggest problem they faced as agrovets was the ethical dilemma of being educated on responsible antimicrobial use while depending on the sales of these products for their business. They found it challenging to steer buyers away from a specific product once their minds were made up. They expressed a desire for stronger regulations to protect their profession, as well as education on antimicrobials for farmers not conducted by pharmaceutical companies promoting their products.

The heavy reliance on antibiotics for treating sick animals, the common practice of self-treatment among farmers, and how past experiences influence drug choices are concerning. Further mapping and surveillance can enhance the precision of interventions aimed at reducing antimicrobial usage.

Keywords: antimicrobial resistance, antimicrobial sales, peri-urban poultry farming, Kenya, ICT

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Abbreviations

AMR	Antimicrobial resistance
AMU	Antimicrobial usage
ICT	Information and Communication Technology
LMIC	Low- and middle-income countries
Mad-tech-AMR	Management of animal diseases and antimicrobial use by information and communication technology to control AMR in East Africa
MRL	Maximum residue limit
VMD	Veterinary Medicine Directorate

1. Introduction

Antimicrobial resistance is a growing global crisis, challenging modern medicine and posing serious threats to public health (Ganewatta *et al.* 2017). The misuse and overuse of antimicrobial substances, particularly antibiotics, have allowed multi-drug-resistant bacteria to emerge.

Urbanization has boomed during recent centuries, with over half of the global population now residing in cities (Satterthwaite *et al.* 2010). The demographic shift is changing not only where people live, but also how they source and consume their food (Tilman *et al.* 2011). Providing nutritious and sustainable food to all people at all times is a challenge facing humanity both presently and in the future. The urbanization trend is notable in Kenya (Cira & Kamunyori 2016), where the increasing population in cities has spurred the development of urban and peri-urban farming (Omondi 2022). Poultry farming has emerged as an important source of protein to meet the escalating demand for meat.

However, the unregulated use of antimicrobial substances in this sector poses a substantial risk given the rise of antimicrobial resistance. In Kenya, the antimicrobial drug market is currently unregulated and there is a lack of data regarding what substances are being used and where (Mutua *et al.* 2023).

Surveillance data is a crucial initial step in addressing the upcoming danger of antimicrobial resistance in order to develop interventions aiming to reduce it (Schar *et al.* 2018). In 2023, a pilot Information and Communication Technologies (ICT) program was launched (Mutua *et al.* 2023), collecting data from antimicrobial sales by veterinary pharmacies in two counties in Kenya with a vision of broader expansion in the future.

This thesis is conducted in collaboration with the International Livestock Research Institute in Nairobi. It is aiming to provide insights for the future development of interventions to reduce antimicrobial usage by analyzing the current sales of antimicrobial substances used in poultry farming in the study site.

2. Literature review

2.1 Urbanisation and urban farming

Over the past few centuries, human society has experienced a remarkable population change. In the year 1800, Earth's population was 1 billion and now we exceed 7.8 billion individuals. Projections suggest that Africa's population will grow more than any other continent until 2050, especially in sub-Saharan Africa where the population is forecast to double (United Nations 2023). Providing nutritious and environmentally sustainable food to the world’s population at all times is a big challenge facing humanity currently and in the future.

At the same time as the world's population is growing, an increasing proportion is moving to the cities. Currently, more individuals reside in urban environments compared to rural regions, and the global urban population surpassed the rural population for the first time in 2008 (Satterthwaite *et al.* 2010).

This urbanization trend is also seen in Kenya, where approximately 27% of citizens now lives in cities, with the yearly rate of urbanization being around 4.3%. While Kenya remains in the early stages of this change, projections suggest that near half of its population will be living in urban environment by 2050 (Cira & Kamunyori 2016).

No country has reached high-income status without urbanization, but urbanization brings new challenges. Urbanization is frequently linked to rising poverty rates, deteriorating health, unstable housing conditions, and food and nutritional insecurity. These challenges are aggravated during economic crises and periods of escalating fuel prices, particularly impacting the urban poor who allocate a large proportion of their income to food expenses (de Zeeuw & Dubbeling 2009).

In low- and middle-income countries (LMICs) like Kenya, increasing incomes have led to a demand for animal protein (Tilman *et al.* 2011). For food security, rural people migrating into urban environments often bring their livestock with them (Thys *et al.* 2005). This, coupled with the demand for increased food production to supply the growing cities has led to the development of urban and peri-urban farming. It provides urban residents with access to affordable, nutritious food while also reducing vulnerability to price fluctuations (Rezai *et al.* 2016).

> "Urban and peri-urban farming is often used synonymously and is defined as the growing of vegetables and keeping of animals within and around the periphery of cities and towns." (Veenhuizen *et al.* 2006).

2.2 Poultry farming in Kenya

With a growing urban population in Kenya, there is an increasing demand for vegetables and animal-sourced protein. In 2014, Kenya's gross national income per capita stood at $1,280, classifying it as a LMIC (Cira & Kamunyori 2016). Poultry is an important source of protein in Kenya, with poultry meat consumption projected to increase from 55 thousand metric tons in the year 2000 to an estimated 165 thousand metric tons by 2030 (Food and Agriculture Organization 2011).

Poultry farming holds a large appeal for urban smallholder households and poultry is the most common livestock kept both for personal consumption and selling. This is due to its efficiency in producing meat and income with minimal feed input, space, and initial investment requirements. The profit is relatively quick compared to other livestock ventures (Omondi 2022).

In 2006, Kenya had approximately 37.3 million birds, with 84% being indigenous breeds, 8.4% layers, 5.7% broilers, and 1.8% other poultry species (Omiti & Okuthe 2008). The Kenyan poultry industry includes both small-scale and large-scale producers operating through two primary systems: indigenous poultry production and the commercial poultry production consisting of layers, boilers and hybrids (Mutua *et al.* 2023). The indigenous system is the most prevalent, contributing to about 71% of the country's total egg and poultry meat production and engaging roughly 75% of rural households.

In the indigenous poultry system, birds often roam freely around the homestead, frequently interacting with wild bird species during their scavenging activities (Okello *et al.* 2010). This makes the implementation of biosecurity as a disease control measure challenging (Mutua *et al.* 2022).

2.3 Kenya veterinary drug distribution chain

The distribution network for veterinary drugs involves various key participants, including farmers, agrovets, distributors, and pharmaceutical companies (Mutua *et* *al.* 2023). In Kenya, agrovets are specialized veterinary pharmacies authorized by the Veterinary Medicine Directorate (VMD) to be managed by licensed veterinary professionals or VMD-authorized individuals (Veterinary Medicines Directorate 2022).

Farmers typically obtain their veterinary drugs primarily from agrovet outlets. The usual practice involves a farmer visiting an agrovet, describing the clinical symptoms they've observed in their livestock, and seeking advice on treatment. Sometimes they bring the sick bird into the store. There are occasions when farmers visit agrovet stores with specific products in mind. They may bring empty bottles, especially if they have previously used the medication and achieved positive results. Some farmers also arrive with prescriptions from veterinarians, although it's not obligatory in order to purchase antimicrobial drugs from an agrovet. The advice given at the agrovet shop will depend on the knowledge of the store attendant. Furthermore, most poultry products are administered by the farmers themselves, making it hard for the agrovet sellers to know if the product was administered as advised (Mutua *et al.* 2023).

In a 2019 Nairobi study of antibiotic retailers, not all serving as veterinary pharmacists had the necessary educational background. Only 57% of the pharmacists had clinical training, and only 41% had formal education in antimicrobial use. The research findings also indicated that all veterinary drug stores in the study dispensed antibiotics without requiring a prescription. The study highlighted that customer preference played a big role in antibiotic prescriptions within half of the drug stores (Muloi *et al.* 2019).

In Kenya, the drug market is currently unregulated, and a prescription is not necessary for buying broad-spectrum antibiotics. This situation poses a substantial risk of development of antimicrobial resistance (AMR), which is further exacerbated by the absence of a structured data system to monitor the usage of antimicrobials among livestock, as pointed out by Muloi *et al.* (2019).

2.4 AMU - Antimicrobial usage

Less than a century ago, minor infections could spell a death sentence, but the discovery of penicillin revolutionized medicine and antimicrobials have since reduced mortality and morbidity in humans and animals. The term antimicrobial encompasses antibiotics effective against bacteria, as well as other substances that combat various microorganisms causing infections, such as viruses, parasites, and fungi (Dadgostar 2019).

Antimicrobial agents are intended for therapeutic purposes in managing infections caused by microorganisms in humans and animals. But antibiotics are not only used for the treatment of infections but also extensively for purposes such as promoting growth, enhancing feed efficiency, and disease prophylaxis in agricultural practices (Woolhouse *et al.* 2015). As of 2017, 73% of all antimicrobials used globally were intended for animal consumption (Mulchandani *et al.* 2023). Although anti-microbial substances are being widely used in agriculture, WHO recognized major gaps in the surveillance of the emergence of AMR in foodborne bacteria originating from food-producing animals (World Health Organization 2014).

Several countries have banned the use of antibiotic growth promoters and critically important antibiotics for human medicine in agriculture, because of the emerging problem with AMR. Sweden banned the use of antibiotics for growth promotion in 1986 and the European union in 2006 (Grundin *et al.* 2020). Despite the implementation of such regulations, it's anticipated that global antibiotic consumption will continue to rise (Van Boeckel *et al.* 2015). According to the projection by Van Boeckel *et al.* (2015), approximately 63,200 metric tons of antibiotics were administered to livestock on a global scale in 2010. Their estimates suggest that by 2030 there will be a notable surge in consumption, with a projected 67% increase to 105,600 metric tons of antibiotic usage in this sector.

In the year 2000, high-income countries were responsible for the highest total antibiotic consumption rates globally (Klein *et al.* 2018). However, by 2015, 4 out of 6 countries with the highest antibiotic consumption rate were considered LMICs. The increase was correlated with growth in per capita gross domestic product and driven by rising living standards in LMICs. A shift towards a more protein-based diet is seen when income rises, which leads to a demand for more intensive livestock farming (Van Boeckel *et al.* 2015). The intensified farming causes a rise in the use of antimicrobial drugs, contributing to AMR.

In many countries, a wide array of antimicrobial agents are used in poultry farming, with a large proportion of the antibiotics used being classified as crucial for human medical practice (Boamah & Agyare 2016). Globally, the most commonly utilized classes of antibiotics in food-producing animals are tetracyclines, followed by penicillin, macrolides, and trimethoprim (Mulchandani *et al.* 2023). Nevertheless, the specific preferences for these substances vary across global regions.

2.5 AMR - Antimicrobial resistance

The misuse and overuse of antimicrobial substances drive the emergence and spread of AMR, a severe global public health threat (World Health Organization

2014). AMR means that a microorganism loses its sensitivity to a drug it was previously susceptible to (Prestinaci *et al.* 2015). The problem of AMR is mainly seen as antibiotic resistance in bacteria. Continuous exposure to antibiotics has led to the development of multidrug-resistant bacteria, often called "superbugs" (Ganewatta *et al.* 2017). The types of antibiotics used in agriculture and in human medicine are mostly the same, thereby increasing the risk of emergence and spread of resistant bacteria (World Health Organization 2014).

AMR can develop through spontaneous bacterial evolution, mutations, and the transfer of resistance genes via horizontal gene transfer (Dadgostar 2019). Resistance is a natural occurrence driven by evolution, but human behavior is a primary factor responsible for accelerating this natural process into one of the most pressing public health crises of the 21st century (González-Bello *et al.* 2020). AMR can be transmitted through direct contact during animal handling or indirectly when consuming food, and it involves the spread of resistant bacteria from animals to humans as well as resistance genes between bacteria in animals and humans. Importantly, this transmission can occur in both directions (Argudín *et al.* 2017).

Bacteria are among the fastest reproducing organisms in the world, *E. coli* bacteria can double their population every 20 minutes (Allen & Waclaw 2019). Bacteria can quickly adapt to selective pressures and readily exchange resistance genes (Ferri *et al.* 2017). New antibiotics are being developed at a far slower pace than bacteria are acquiring resistance (Silver 2011). Most of the discovery of various classes of antibiotics occurred between 1949 and 1980. Ever since, there has been a notable absence of major antibiotic developments, with no successful discoveries of a fundamentally new class of antibiotics since 1987. This period is often referred to as an “antibiotic discovery void”.

The economic impact of AMR is hard to quantify but increased resistance leads to longer therapy with more expensive antibiotics, longer hospital stays and isolation procedures for the patients (Prestinaci *et al.* 2015). Social impacts include more serious illness, loss of productivity and death.

2.6 Antimicrobial surveillance

Surveillance is a pivotal initial step in controlling and preventing AMR and establishing standardized, internationally comparable data could accelerate the progress in optimizing global AMU (Schar *et al.* 2018; Simonsen 2018). Surveillance data regarding both antibiotic usage and resistant bacteria is essential for estimating the extent of usage, monitoring trends, identifying emerging resistance patterns, and assessing the impact of intervention measures. Understanding current practices can greatly enhance the precision of interventions aimed at reducing antimicrobial usage.

Currently, Kenya lacks regulations for AMU, allowing these substances to be purchased from agrovet stores without requiring a prescription, as reported by Mutua *et al.* (2023). This lack of regulation in many LMICs poses a challenge in controlling AMR.

In 2015, WHO pointed out that data on AMU is lacking from LMIC and introduced a global action plan to address AMR (World Health Organization 2015). They pointed out the need to build a database on AMU in animals, which led to the "Annual report on antimicrobial agents intended for use in animals" by the World Organization for Animal Health (World Organization for Animal Health 2022).

While the lack of data is more pronounced in less developed countries, with the annual report having the lowest coverage in Africa, there is limited information available regarding the extent of antibiotic usage in highly developed countries as well. WHO also acknowledges in their report the vital role of healthcare workers in preserving the effectiveness of antimicrobial medicines (World Health Organization 2015). Inappropriate prescribing and dispensing of antibiotics can lead to misuse and overuse, especially when medical staff lack up-to-date information, cannot identify the type of infection, yield to patient pressure for antibiotics, or benefit financially from providing these medications.

The WHO also recognizes that reducing AMR will require the political will to implement new policies, including controlling the use of antimicrobial medicines in human health and food production (World Health Organization 2014). In the report from 2014 on the surveillance of AMR, WHO underscores the need for the development of tools and standards for consistent monitoring of AMR in bacteria from both humans and food-producing animals.

2.7 Antimicrobial substances

2.7.1 Tetracyclines

Tetracycline antibiotics are renowned for their wide-ranging effectiveness against various bacteria, including gram-positive and gram-negative bacteria, spirochetes, intracellular bacteria, and protozoan parasites (Grossman 2016). They were first discovered as natural compounds from actinomycetes bacteria in 1948. Tetracycline antibiotics work by attaching to a part of the bacterial ribosome, thus preventing bacteria from making essential proteins.

Resistance to tetracycline antibiotics emerged shortly after their introduction in 1953 (Thaker *et al.* 2010). Resistance has rapidly spread among bacteria due to the exchange of resistance genes and can develop through different mechanisms, but currently, the main resistance mechanisms in clinical settings are active efflux of tetracycline from the cell and the production of ribosomal protection proteins.

In a 2016 study conducted in Nigeria, researchers examined enterococci, which are commonly found in chicken feces, to determine whether they carried tetracycline resistance genes that could potentially be transferred to humans through gut bacteria (Ayeni *et al.* 2016). The study revealed a tetracycline resistance rate of 82% in the samples. All the isolates in the study were resistant to erythromycin, of the class macrolides.

2.7.2 Macrolides

Macrolides, primarily produced by *Streptomyces* bacteria, were first discovered in the 1950s (Dinos 2017). They inhibit bacterial protein synthesis by targeting the ribosome. Macrolides are broad spectrum antibiotics active against gram-positive and some gram-negative bacteria. They are particularly useful in the treatment of infections with *Mycoplasma* spp., *Chlamydia* spp., *Campylobacter* spp. and constitute an important alternative to use for people with penicillin hypersensitivity (Kanfer *et al.* 1998).

Macrolides are the preferred treatment option for severe cases of campylobacteriosis, a foodborne illness causing gastroenteritis that can be acquired via consumption of under-cooked or cross-contaminated poultry meat (Bolinger & Kathariou 2017). However, the increased incidence of macrolide resistance limits the effectiveness of these antibiotics. In 2013, the American Centers for Disease Control and Prevention identified *Campylobacter* strains resistant to fluoroquinolones and macrolides as a public health concern (Centers for Disease Control and Prevention 2013).

A study investigating macrolide resistance in *Campylobacter* bacteria isolated from South Korean poultry between 2013 and 2016 (Wei & Kang 2018) identified a compelling prevalence of resistance to two types of macrolides, with 27 out of 38 strains exhibiting resistance to both antibiotics via genetic mutation and drug efflux. The authors of this study point out the need for further research concerning macrolide resistance is pointed out by the south Korean study to investigate this resistance and specific genetic changes.

2.7.3 Sulfonamides

Sulfonamides are a group of synthetic antibiotics with broad spectrum effects against most gram-positive, gram-negative bacteria and protozoa (Sköld 2000). Sulfonamides are frequently used in the Kenyan poultry industry for therapeutic, prophylactic or growth-promoting purposes (Mutua *et al.* 2023). Their mechanism of action is by targeting a specific enzyme that is crucial for bacterial growth (Sköld 2000).

In 2003, sulfonamides were grouped into a category of veterinary medicines with a high risk to pollute the environment and of high global usage (Boxall *et al.* 2003). A 2014 study in China revealed that fertilizing with antibiotic-polluted manure had a large impact on the selection of sulfonamide-resistant bacteria in the soil (Wang *et al.* 2014). This influence arises not only from the spread of bacteria carrying antibiotic-resistant genes but also from the scattering of antibiotic residues, which further promotes the selection of resistant bacteria.

In a study conducted in Tanzania, where 96 eggs from commercial layer chicken farms were examined, it was found that all the analysed samples contained sulfadiazine, a type of sulfonamide (Mubito *et al.* 2014). Additionally, 29% of these samples contained residues that exceeded the maximum residue limit (MRL). In the general population, approximately 3–8% of patients are reported to experience a sulfonamide allergy, which makes residues exceeding the MRL in food such as eggs a major health risk to the consumers (Giles *et al.* 2019).

2.7.4 Polymyxins

There are five polymyxins (A to E) of which two are used in clinical setting, polymyxin B and polymyxin E (Colistin) (Landman *et al.* 2008). Polymyxins were discovered in the 1940's and are derived from *Paenibacillus polymyxa.* They are effective against a wide variety of gram-negative pathogens with a bactericidal effect. Due to its systemic toxicity colistin was initially replaced with other less toxic antimicrobial substances but since the rise of multiresistant "super-bugs" it's been reintroduced as a last-resort antimicrobial in human medicine (Poirel *et al.* 2017).

Polymyxins bind to the bacterial membrane, causing damage and cytoplasmic leakage (Landman *et al.* 2008). They are also able to neutralize endotoxins and enhance the susceptibility of gram-negative bacteria to other antimicrobials when used in combination. Colistin is being extensively used in poultry and pig production to treat gastrointestinal infections, but its effectiveness has been proven limited in poultry due to poor absorption in the gastrointestinal tract (Goetting *et al.* 2011).

Polymyxins such as colistin serve as a final resort in treating numerous multidrug-resistant bacteria (Moffatt *et al.* 2019, Poirel *et al.* 2017). However, their heightened usage has led to the alarming emergence of resistant strains. The primary means by which bacteria develop resistance to polymyxins involves alterations in their outer membrane lipopolysaccharides, which are the binding sites for polymyxins. Nevertheless, a wide spectrum of resistance mechanisms exists, collectively diminishing bacterial susceptibility to polymyxins.

2.7.5 Aminoglycosides

Aminoglycosides are commonly used broad-spectrum antibiotics to treat infections caused by both gram-negative and gram-positive organisms (Nowacka-Kozak *et al.* 2023). They were among the earliest antibiotics to be developed and are either natural or semisynthetic, derived from *Actinomycetes* bacteria (Krause *et al.* 2016). Aminoglycosides exert synergistic effects with various other classes of antibiotics and function by inhibiting bacterial protein synthesis.

Aminoglycosides play a crucial role in veterinary medicine for the treatment of infections in major food-producing animals, and they have been classified as important antimicrobials for human medicine by the World Health Organization (Collignon *et al.* 2016).

They are poorly absorbed through the gastrointestinal tract, but they are predominantly excreted in the urine without undergoing metabolism and are consequently frequently used to treat urinary tract infections (Craig 2011). As the medications can exit the body unchanged via urine, they can enter the environment and contribute to the selection of drug-resistant bacteria (Serrano & Silva 2006). In a study conducted in the US between 1999 and 2000 where Enterococci from poultry carcasses were examined, 46% exhibited high-level resistance to three types of aminoglycosides (Jackson *et al.* 2004).

2.7.6 Antihelmintics and anti-coccidials

Parasites causing health problems and economic losses are among the most common infections in humans and animals (Ahmad 2023). Common internal parasitic infections in poultry include nematodes, cestodes and coccidia. They can cause malnutrition, decreased feed conversion efficiency, weight loss, lowered egg production, and mortality in young birds (Puttalakshmamma *et al.* 2008).

Due to their scavenging behavior in free-range environments, helminth parasitism is highly prevalent among rural chicken populations globally (Saemi Soudkolaei *et al.* 2021). The parasitic infestation causes both clinical and subclinical diseases and is affecting both poultry health and food production.

To manage and treat internal parasitic infections, pharmaceutical anthelmintics have been widely used. These drugs function by either immobilizing or lethally damaging internal parasites (Patel *et al.* 2018). Examples of anthelmintic classes include benzimidazoles, macrocyclic lactones, and imidazothiazoles. The primary causes of anthelmintic resistance include the parasite's ability to expel drugs more effectively, break down drugs faster, alter drug-binding sites to reduce drug effectiveness, and reduce the number of drug receptors on the parasite (Fissiha & Kinde 2021).

Coccidiosis is one of the major parasitic diseases of poultry and is caused by the protozoa *Eimeria* spp. (Dalloul & Lillehoj 2006). Coccidiosis hinders the growth and food efficiency of infected animals, leading to decreased productivity and great economic loss. Common approaches for managing this disease predominantly involve the use of anticoccidial drugs, along with the limited utilization of live vaccines (Abbas *et al.* 2011). When anticoccidials are administered, this is frequently done through the feed or water to all animals in the population in a prophylactic manner rather than a therapeutic one. This practice has resulted in the development of drug resistance and reduced efficacy of anticoccidials.

These medications are typically composed of various compounds that target different stages of the parasite's life cycle or disrupt essential pathways within the parasite (Chapman & Rathinam 2022). Anti-coccidials often include different classes of drugs such as ionophores, amprolium, nicarbazin, as well as antibiotics such as sulfonamides. These drugs may be used alone or in combinations to enhance their effectiveness against coccidiosis.

The inclusion of antibiotics in these medications often aims to enhance their efficacy by also targeting bacterial infections that may accompany coccidiosis or to counteract secondary infections caused by weakened immune systems due to the primary disease. However, concerns about antibiotic resistance and residues in edible tissues have led to certain antibiotics being withdrawn or limited in use in some regions or formulations (Chapman & Rathinam 2022).

3. Materials and Methods

This thesis is part of the MAD-tech-AMR (Management of animal diseases and antimicrobial use by information and communication technology to control AMR in East Africa) project conducted by the International Livestock Research Institute in Nairobi, Kenya in collaboration with Makerere University in Uganda and coordinated by the Swedish University of Agricultural Sciences (SLU), in Uppsala. This thesis aims to analyse the current practice of agrovets' antimicrobial sales and examine previously collected sales data from the study site during the time period of May 10, 2023, to August 28, 2023.

3.1 Study site

The project was conducted within peri-urban and urban regions of Kenya, in the counties of Machakos and Kajiado located to the south of Nairobi, as shown in Figure 1. Data from agrovets were collected from these particular counties due to their substantial poultry population and their important role as key suppliers of poultry products to the capital city of Nairobi.

Figure 1. Map illustrating Machakos county in green and Kajiado county in blue. The country of Kenya is illustrated in purple. Map created in 2023, using Mapchart net (https://www.mapchart.net/index.html

3.2 Baseline study

In order to develop an AMU reducing intervention, an analysis was done of the current distribution system and usage of veterinary drugs in peri-urban poultry systems in two Kenyan counties. The project started out with key informant interviews to create a baseline study in April and May 2021, described in Mutua *et al.* (2023). Farmers, veterinarians working with the county government, agrovet shops and animal health providers were interviewed. Questions about the sources and veterinary drugs, handling of expired products, disposal of drug packages and public health risks due to AMU were asked.

A total of 706 records of AMU practice were noted in the study. Out of the records, 43% was antibiotics, 20% vitamins, 12% acaricides, 10% dewormers, 8% disinfectants, 2% anticoccidials and 2% other products. The reason for administrating veterinary drugs in addition to treating sick animals was also prevention (78%), to boost growth (41%) and to treat human infection (8%). 89% of the leftover antibiotics were stored for later use and 11% were disposed of (Mutua *et al.* 2023).

The most observed classes of antibiotics used were tetracycline (65%), macrolides (39%), sulfonamides (31%), polymyxins (18%) and aminoglycosides (18%). 65% of the antibiotic products recorded contained multiple ingredients. The predominant method of drug administration among the farmers was via water (98%), with minimal usage through feed (1%) and topical applications (1%), primarily for eye infections (Mutua *et al.* 2023).

3.3 Focus group interviews with agrovets

During the 28th and 29th of September, two focus groups were convened for one-hour-long interviews with the aim of gathering feedback on the agrovets' experiences with participation in the project. A total of 12 agrovets participated, 7 in Kajiado and 5 in Machakos. Before the interviews, the agrovets signed a consent form agreeing to be voice recorded (see Appendix 1). The interviews were conducted in English as part of this thesis, with the assistance of a translator for any Swahili words. The translator also aided in note-taking.

The agrovets were asked about their thoughts on the project, the areas they found challenging, and how they recorded their sales (see Appendix 2). In addition to the technical aspects of the project, the agrovets were also asked about how they perceived their role as retailers in addressing the issue of AMR. For example, to what extent they could influence farmers' purchasing decisions, and how they responded when farmers requested specific medications. The answers were transcribed from the recording and summarized.

3.4 Drug sales data

Within the project, an Information and Communication Technology (ICT) tool was then developed and introduced to a total number of 14 agrovets, 8 in Kajiado and 6 in Machakos. The agrovets were given tablets in order to use the ICT system to start tracking their sale of drugs. For each sale, they entered the name, size and quantity of the medicine. They also stated the reason for the visit, if a specific product was being requested and with what reference, such as an empty container, old example, new prescription, old prescription or no prescription. They also stated for what species the drug was being sold for.

During the period from May 10, 2023 to August 28, 2023, there was a total of 7043 drug sales intended for animals. Out of these, 2842 were for poultry. The poultry sales data were downloaded as an MS Excel file and cleaned. The counties in the file received are anonymized and referred to as “County 1” and “County 2” within this thesis. A chi-square test was conducted using Epitools (Epitools 2023), to examine instances where differences were seen between the two counties.

The sales were categorized into what type of drug was being used, with the main categories antibiotics, anti-coccidia, anti-helmintics, anti-protozoals, vitamins and combinations of them. The antibiotic drugs were divided into what substance they consisted of.

4. Results

4.1 Focus group interviews

A total of 12 agrovets participated in two focus group interviews – 7 in Kajiado and 5 in Machakos. All participating agrovets were still actively involved in the program and utilized the ICT tool on the provided tablets to record their sales. The majority of the agrovets were licensed veterinarians.

4.1.1 Perception of the ICT tool

All participants expressed overall satisfaction with the project, thinking the tool works well. They thought it's providing them with insights they hadn't noticed before about the movement of antibiotics. One participant highlighted the impact on their awareness of antibiotic usage, stating, *"When you're not collecting data you don't notice what antibiotics you're selling, like oxytetracyclines for me, but the system evidently shows you."*

Several participants encountered challenges in the initial days of using the app, with the primary issue being lagging tablets. They contacted the IT support team which quickly resolved the problem, and now the system operates smoothly. Another early issue was the absence of some drugs in the system. It took 2-3 weeks and then most of the drugs were in the system. Some ointments containing antimicrobials are still missing, and some agrovets express a desire for vaccines to be added into the system.

Another challenge they encountered in the beginning was the impression that sales needed to be registered instantly, leading to disruptions during peak hours. Subsequently, they adopted alternative techniques for registering sales.

4.1.2 Recording sales

The agrovets are recording sales in different ways. Some register sales instantly during quieter store hours, while others maintain a notebook and register all daily sales at the day's end into the system and some accumulate several days' worth of sales before registering them. The time consumption for this process varies based on their sales volume but can take up to one hour a day. One agrovet appreciates that 90% of their antimicrobial sales are recorded.

Peak store hours are in the early mornings and afternoons, with peak days occurring on Fridays, weekends, and Mondays. During these high-traffic periods, most agrovets take notes and register sales afterward.

4.1.3 Interactions with the buyer

4.1.3.1 Factors impacting the choice of medication

Sometimes, farmers bring their birds into the store, giving the agrovets an idea on what they are treating. However, according to several participants, farmers very frequently bring a note with the medication's name written, a picture on their phone, or someone on the phone who orders the medication. *"The choice of medication is ideally determined by the disease it is intended to cure, but that's not always the case."*

One agrovet mentioned that they prefer choosing larger pharmaceutical brands, thinking that they are better. They often receive feedback from customers regarding specific medications and brands, as well as consulting with other agrovets, and partially base their choice of medication on that.

4.1.3.2 Extent of influence on purchasing choices

The extent of influence on purchasing choices varies a lot depending on the buyer. "People who are willing to listen can be guided in another direction. But there are those you can't change, especially when they bring photos of the drug. There's almost nothing you can do; you just dispense even though your conscience is questioning if you did the right thing." Many agrovets agreed on that if buyers come into the store seeking consultation, they can guide them in a certain direction. If the buyers are certain about what they want, it's more challenging.

4.1.3.3 Responding to requests for a certain medication

Even if the buyers are requesting a certain medication, several of the agrovets always start out by taking a history, asking about the symptoms, cases of mortality and if they have done any post mortem examination. But if the buyers insist on a medication, they sell it. One of the participants said that since getting the tablet, they have begun to ask what medication the buyer has already tried since they might not be the first agrovet the buyer visited.

4.1.4 The agrovets' thoughts on AMR

4.1.4.1 Agrovets' role in antimicrobial sales

Several of the participants experience the dilemma of being educated about the problem of AMR but still running a business that depends on the sales of the substances. They feel like the farmers are overusing and misusing antimicrobials, especially antibiotics, but have no choice but to dispense to them. *"Sometimes you find yourself doing the contrary of the advised to the health of the public, but if you don't sell to the customer, he will just go to the next shop. It's a dilemma of protecting our profession but still having a business."*

When asked about if they would want a requirement of a prescription in order to buy antibiotics, the agrovets' were not keen since it would affect their businesses dramatically. Instead, they wish that the sales were restricted to only educated people. According to the Veterinary Medicines Directorate (VMD), an agrovet store has to be linked to a veterinarian in order to sell antimicrobials, but the agrovets know about instances where it's not the case. They tell about instances where uneducated people sell antimicrobials whilst not knowing enough about it. They wish for the VMD to protect and care more for them.

4.1.4.2 Consideration of AMR in the daily work

When asked about their consideration of AMR in their daily work, several agrovets share that it has always been at the back of their head, but the current project has brought greater awareness to the issue. They primarily emphasize the challenge they face: despite possessing knowledge about the dangers of AMR and attempting to persuade buyers to explore alternatives to antimicrobials when they are not the appropriate solution, they lack authority. Buyers can easily choose to go to another shop, undermining the agrovets' efforts.

One agrovet expressed growing concern about the adherence to withdrawal periods. While agrovets provide advice to buyers and educate them about withdrawal times, they have no control over whether these guidelines are followed. The agrovet now worries about the potential impact on themselves and their own family if withdrawal periods are not observed. This has led several of the participants to now refrain from eating eggs and poultry meat themselves.

4.1.4.3 Ideas on optimizing future use of antimicrobials

The agrovets express a desire for additional training on AMR for farmers. Currently, there are antimicrobial training sessions organized by pharmaceutical companies. However, a concerning issue has surfaced – during these sessions, farmers are encouraged to purchase antibiotics unnecessarily. Agrovets recounted instances where farmers present extensive lists of antibiotics without any apparent health issues in their animals. Upon inquiry, it becomes evident that these medications are all from the same company, leading the agrovets to believe that farmers are influenced by salespeople that aren't veterinarians to make these purchases during the training sessions. This is something the agrovets believe should not be allowed.

Furthermore, there have been reported cases of the salespeople directly selling medications to farmers during these trainings. This has resulted in instances of incorrect dosages being administered and the farmers then seek veterinary assistance only after encountering the problems. Another area of concern with potential for improvement is the VMD. The participants emphasized that while they do not necessarily advocate for a prescription requirement for purchasing antimicrobials, they urge the VMD to implement stricter regulations to control the sale of drugs. They propose limiting sales to only qualified individuals with the appropriate education. Although existing rules support this notion, agrovets feel that the VMD lacks sufficient strictness in enforcing these regulations.

4.2 Antimicrobial sales data

4.2.1 Visit reason

The data indicate various reasons for farmers' visits related to antimicrobial sales in poultry farming, ranging from seeking advice on husbandry to treating sick animals or buying drugs for disease control as seen in Figure 2, 3 and 4. The most common reason for visits in the overall dataset was due to sick animals. Agrovets in county 1 registered more visits due to animals being sick (69%) compared to county 2 (62%) but notably less visits for preventive medicine (4%) compared to those in county 2 (13%). These differences were significant ($p<0.05$).

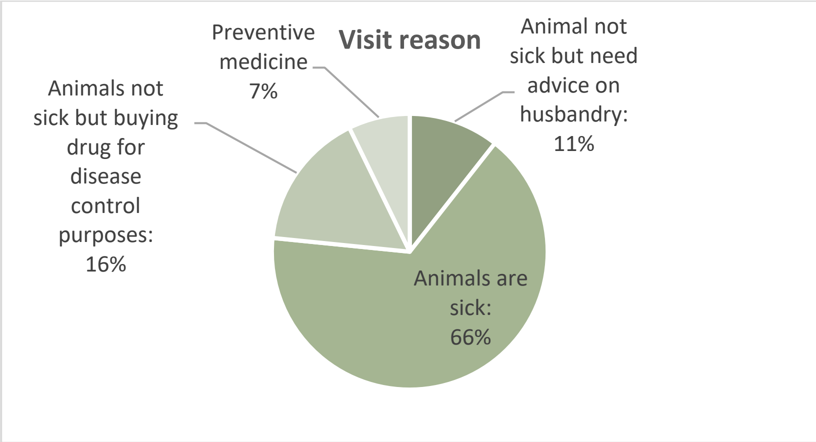
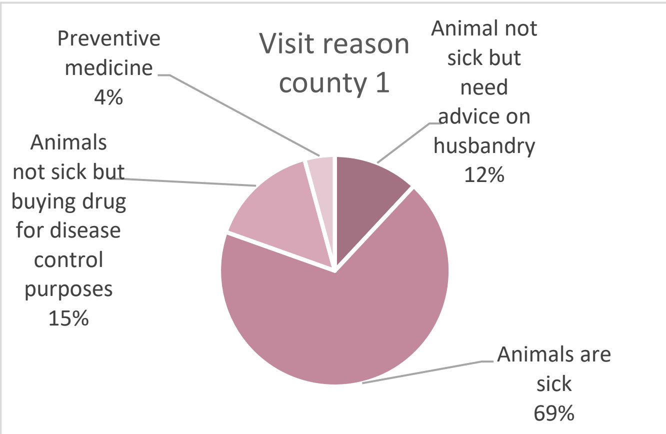


Figure 2. Visit reasons for antimicrobial sales based on all collected data.



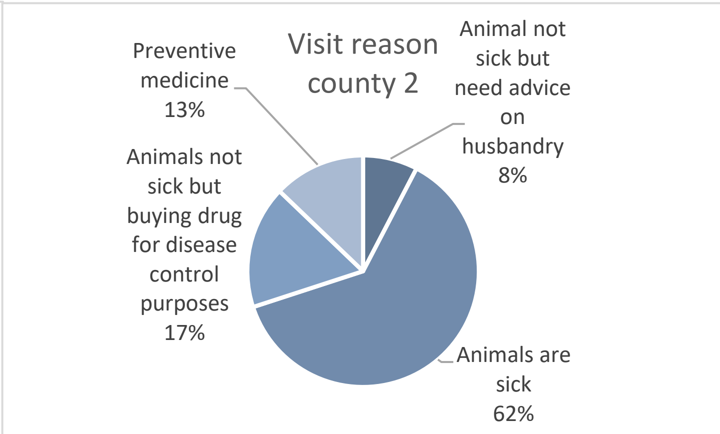


Figure 3. Visit reasons for antimicrobial sales in county 1.

Figure 4. Visit reasons for antimicrobial sales in county 2.

4.2.2 Reference for purchase

Figure 5 illustrates the sources or references farmers used when purchasing antimicrobials, such as new prescriptions, old prescriptions, no references, pictures of sick birds, etc. Most common was a new prescription (33%) and no reference (31%). Least common was to bring a sick bird to the agrovet (3%). The types of sources used were very similar between the two counties.

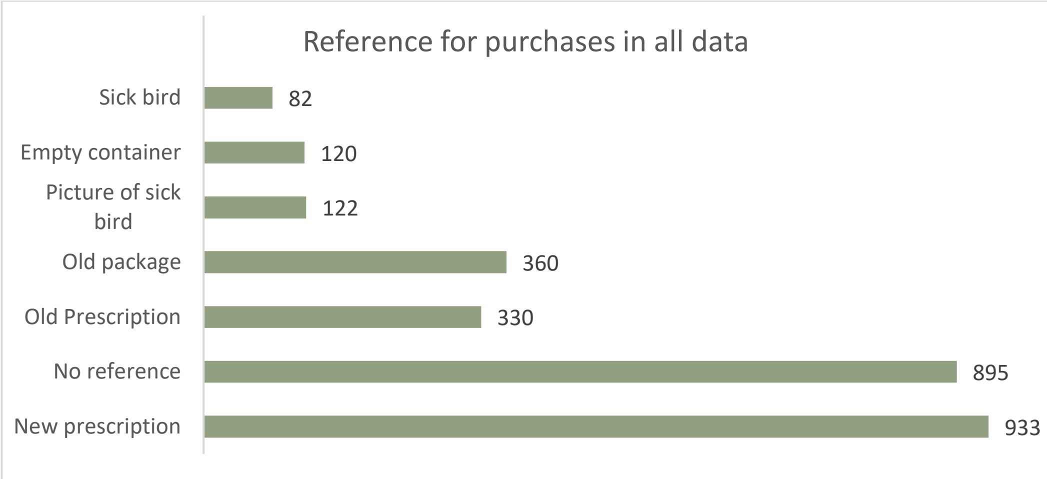


Figure 5. References used for purchase in all data.

4.2.3 Requests for specific products

Table 1 shows cases where a specific antimicrobial product was requested by the farmer versus cases where no specific request was made. Among all data, 34% of buyers requested a specific product. There was a significant difference between the two counties ($p<0.05$).

Table 1. Table depicting the frequency of requests for a particular product among farmers across all data, as well as in County 1 and County 2.

Is a specific product requested?			
All data			
	Yes	962 (34%)	
	No	1880 (66%)	Total: 2842 (100%)
County 1			
	Yes	532 (28%)	
	No	1336 (72%)	Total: 1868 (100%)
County 2			
	Yes	392 (43%)	
	No	511 (57%)	Total: 903 (100%)

4.2.4 Types and substances of drugs sold

Figure 6 shows the types of drugs used in poultry farming in the counties, such as antibiotics, anti-coccidials, vitamins, and others. Almost two thirds of the purchases (64%) contained antibiotics and only 11% were anti-helmintic and 10% pure anti-coccidial. The types of drugs used were very similar between the two counties.

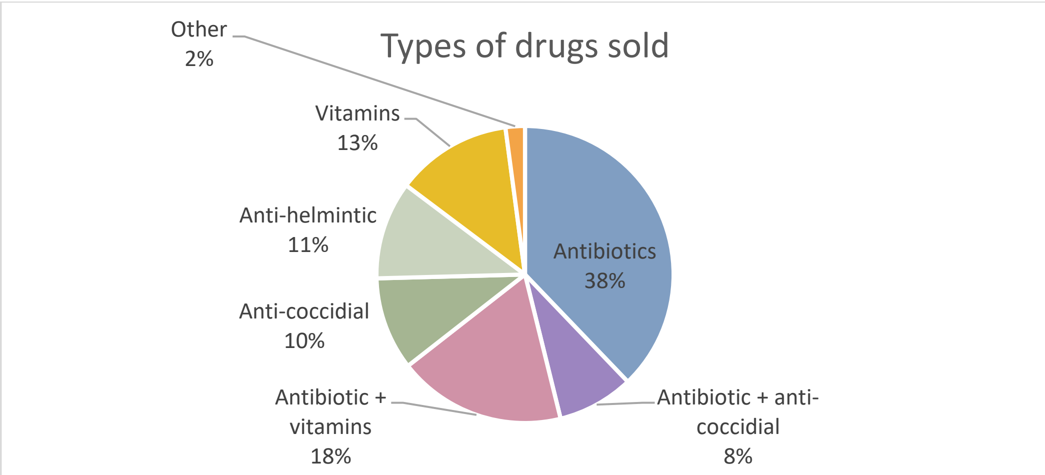


Figure 6. This chart describes the prevalence of various antibiotic substances used in poultry farming in Machakos and Kajiado.

Figure 7 illustrates the most frequently purchased antibiotic substances by weight across the entire dataset. It shows that oxytetracycline, both by itself and combined with vitamins or other antibiotics like erythromycin, streptomycin, and neomycin was among the most frequently purchased. Additionally, the combination of tylosin and doxycycline stood out as another commonly purchased combination.

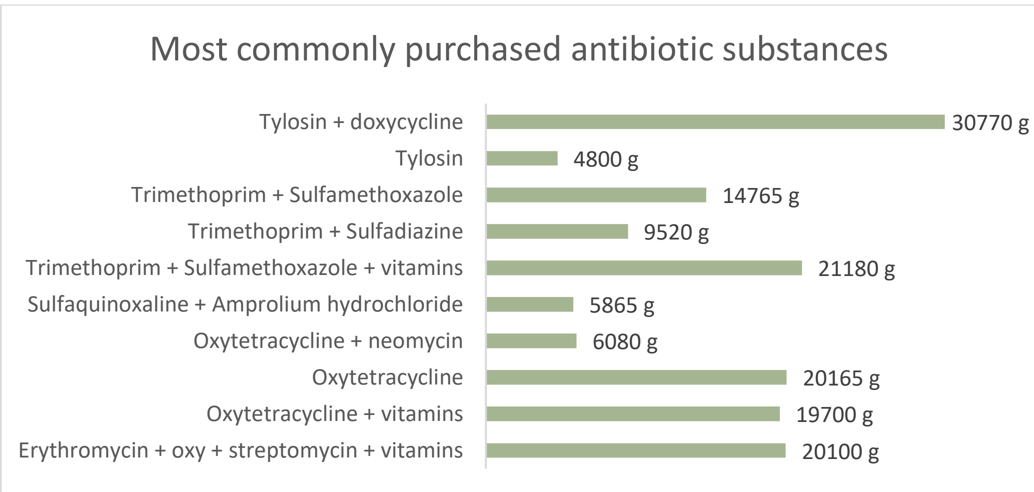


Figure 7. Chart displaying the most frequently purchased antibiotic substances by weight across the entire dataset.

Figure 8 depicts a comparison between county 1 and county 2, showing the percentage distribution of commonly purchased antibiotic substances based not on weight but the frequency of purchases. It shows that oxytetracycline combined with vitamins was the most common purchase in both counties. The second most common purchase was in county 1 sulfamethoxazole + trimethoprim + vitamins. The second most common purchase in county 2 was tylosin + doxycycline.

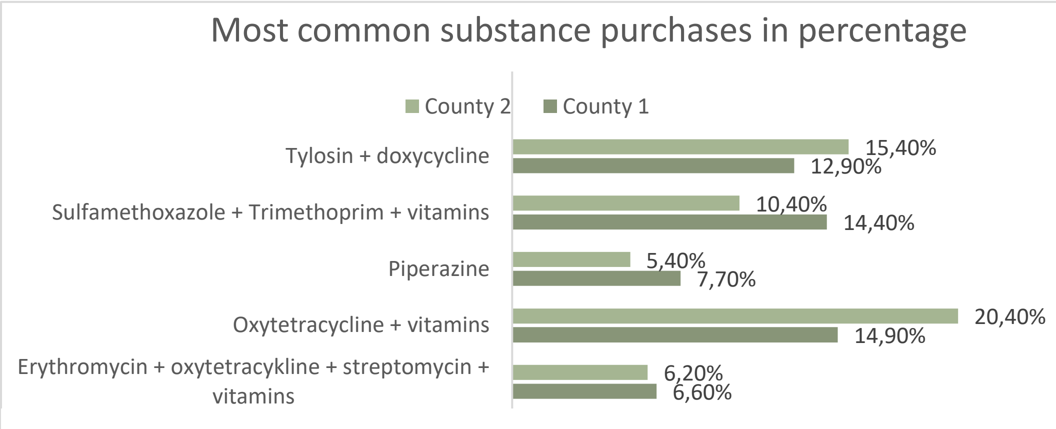


Figure 8. Comparison of the percentage distribution of commonly purchased antibiotic substances in County 1 and County 2.

Among the less commonly used antibiotics in the dataset were substances such as cloxacillin, cefalexin combined with kanamycin, and doxycycline. These antibiotics represented a smaller portion of the overall antibiotic purchases. Combinations like colistin with ampicillin, oxytetracyclines or doxycycline were also observed less frequently in the dataset.

As seen in Figure 11, 68% of the purchased antibiotics were composed of multiple antibiotic classes and 32% contained a single antibiotic. There was a significant difference ($p<0.05$) between the counties, where 70% of the purchases contained multiple classes in county 1 (Figure 13) compared to 61% in county 2 (Figure 12).

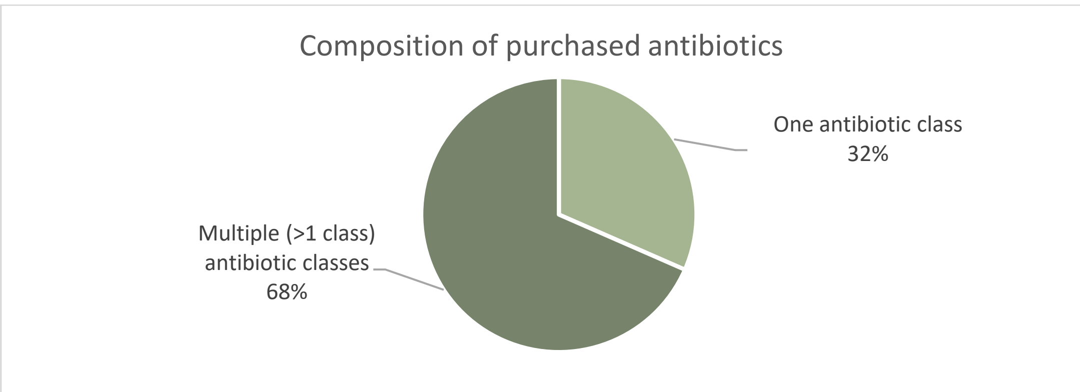


Figure 9. Distribution of purchased antibiotics containing one or multiple antibiotic classes.

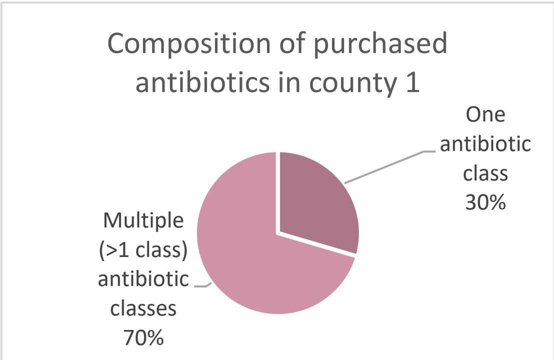


Figure 11. Distribution of purchased antibiotics composed of one versus multiple antibiotic classes in county 1.

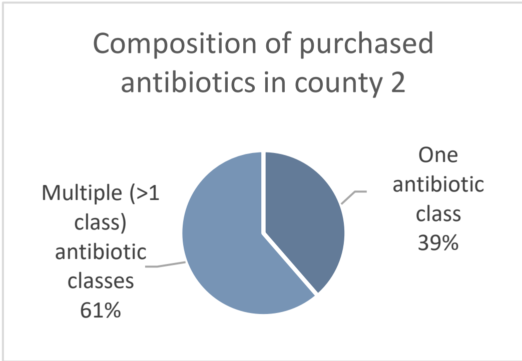


Figure 10. Distribution of purchased antibiotics composed of one versus multiple antibiotic classes in county 2.

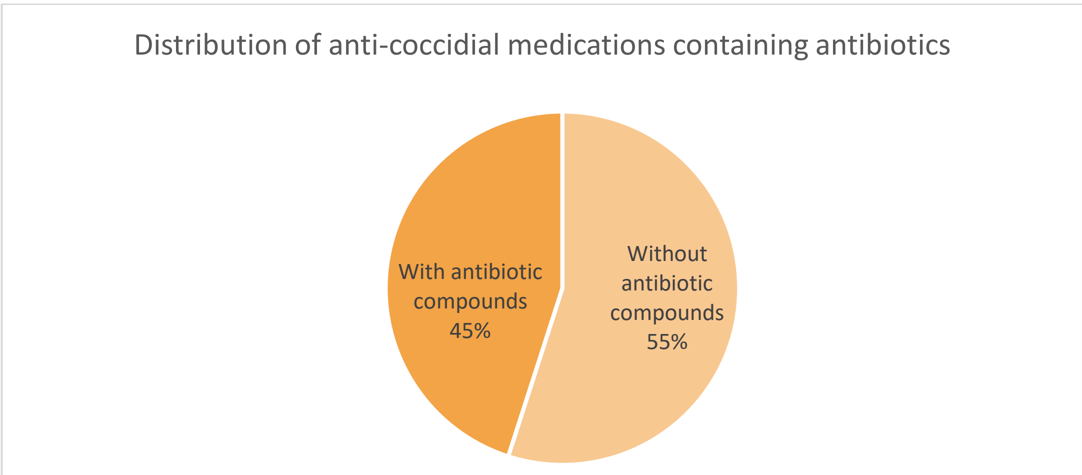


Figure 12. Distribution of purchased anti-coccidial medications containing antibiotics.

Among the 524 purchases of anti-coccidial medications, which accounted for roughly 18% of all purchases (as illustrated in Figure 8), 45% included antibiotics while the remaining 55% did not, as shown in Figure 14. The predominant antibiotic found in 88% of these antibiotic-containing anti-coccidials was sulfamethoxazole and trimethoprim.

As seen in Figure 15, the most prominent substances in purchases of anthelminthics were Piperazine (66%) and Levamisole (29%).

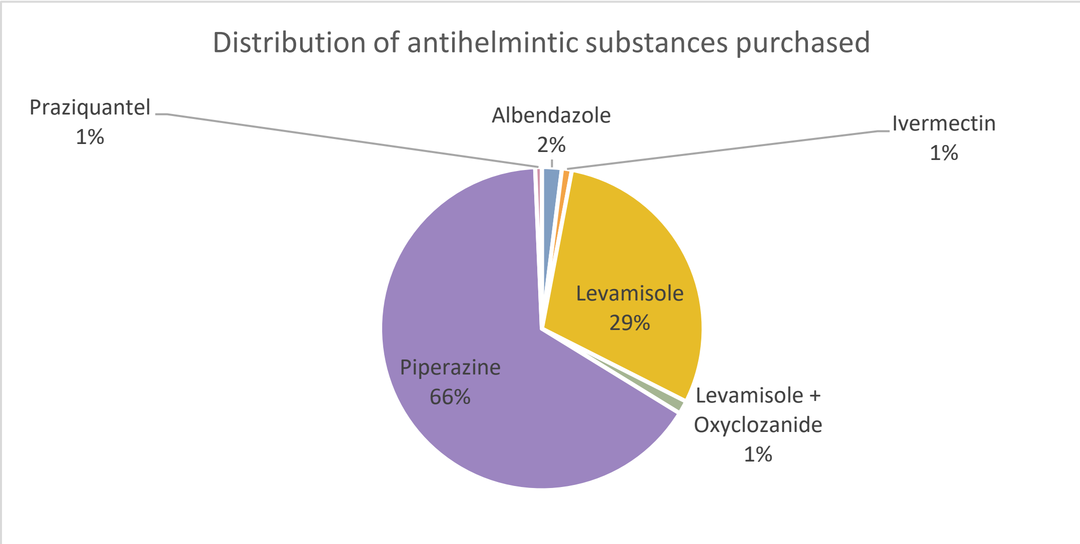


Figure 13. Distribution between the anti-helminthic substances purchased.

5. Discussion

5.1 Focus group interviews

5.1.1 Registering antimicrobial sales

The findings from the interviews with the agrovets shed light on several critical aspects of antimicrobial sales in poultry farming. The implementation of the MAD-tech-AMR application appeared to be a first meaningful step forward in providing agrovets with valuable insights into their antibiotic sales. Despite initial technical glitches and delays in incorporating certain medications into the system, the overall satisfaction among participants indicates the potential of such technological interventions in monitoring and regulating antimicrobial sales. In the future, the development of this application could be useful in attempting to create an overview of antimicrobial use in farming at a national level.

However, challenges persisted, notably during peak store hours, where agrovets encountered disruptions when trying to register sales while also running a store. This led to the adoption of alternative registration techniques, indicating the need for more efficient and less time-consuming methods to record sales without interrupting daily operations. Different practices in recording sales among agrovets raise concerns about data consistency.

To further expand this project in the future, implementing a more efficient and user-friendly method to record antimicrobial sales such as automatic recording through barcode scanning could alleviate the time-consuming task for agrovets and ensure more accurate data with less human errors.

5.1.2 Agrovet-buyer interactions

The interviews highlighted the difficult dynamics influencing buyer decisions regarding medication choices. While some buyers sought guidance and advice from agrovets, a substantial proportion arrived with predetermined preferences. These were often influenced by previous experience, external advice or as believed by the agrovets, pharmaceutical companies. This divergence in behaviour highlights the need for the right education not only for agrovets but also for the poultry farmers. Enhanced communication strategies aimed at dispelling misconceptions and fostering informed decision-making could contribute to more responsible anti-microbial use in the poultry sector.

5.1.3 Ethical dilemmas and professional responsibilities

One of the most striking revelations by the interviews was the ethical dilemma faced by agrovets regarding antimicrobial sales and AMR. Despite their awareness of the adverse effects of antimicrobial overuse on public health, they have to tend to the necessity of sustaining their businesses. This dual role as educators on AMR and sellers of antimicrobials results in an ethical dilemma.

This challenge highlights the fine line between professional responsibilities and financial sustainability. The reluctance toward prescription requirements for antibiotic purchases reflects their concerns about potential business implications, showing the need for nuanced regulatory frameworks that balance public health concerns with economic realities for the agrovets.

The interviews revealed a shift in the agrovets' awareness of AMR and its implications. While AMR had always been on their mind, the current project brought forth a heightened sense of responsibility. Concerns regarding withdrawal periods and potential health implications for themselves and their families if guidelines are not followed signal a growing personal stake in advocating responsible antimicrobial use.

5.1.4 Optimizing antimicrobial use in the future

The agrovets' ideas on optimizing future antimicrobial use encompass multifaceted strategies. They proposed enhanced farmer education, stricter regulations to control sales, and empowering regulatory bodies to enforce existing rules more rigorously.

The agrovets expressed concerns about current training sessions run by the pharmaceutical industry that promote unnecessary antibiotic purchases and sales by unqualified individuals. They advocated for enhanced education for farmers, not solely conducted by the pharmaceutical companies attempting to sell their anti-microbial products, but rather focusing on responsible antimicrobial use and withdrawal periods.

They also called for stricter regulations by the Veterinary Medicines Directorate (VMD) to control sales and restrict them only to qualified personnel. Several instances where unqualified individuals sold antimicrobials in agrovet stores indicate that the current rules weren’t enforced sufficiently. The participating agrovets seek more protection and stronger rules from the VMD to ensure safer antimicrobial sales and reduce the risk of antimicrobial resistance.

5.2 Antimicrobial sales data

5.2.1 Total data

5.2.1.1 Visit reason

The high number of visits where animals are sick (n=1875) indicates a substantial reliance on antimicrobials for treating poultry illnesses. However, the count of visits where the farmer is seeking advice on husbandry without animals being sick (n=301) suggests a proactive approach by some farmers. This could indicate a desire for preventive measures or a proactive attitude toward poultry health. The counts for visits aimed at buying drugs for disease control purposes (n=460) and preventive medicine (n=205) shows a recognition of the importance of disease prevention strategies among farmers, although there is a risk of antimicrobials being used excessively.

5.2.1.2 Purchase reference

The high number of new prescriptions (n=933) and absence of references (n=895) suggest both a reliance on veterinary consultations as well as widespread self-medication without professional guidance. The habit of presenting old prescriptions (n=330) and used packages (n=360) may indicate either repeated prescriptions or the reuse of previously prescribed medications. This practice could potentially lead to misuse, suboptimal treatment, and increased development of antibiotic resistance. It's widely acknowledged that antibiotic misuse stands as a significant factor in the emergence of antibiotic resistance. Additionally, in settings where self-prescription is possible, there tends to be a reduced inclination to seek veterinary services (Boamah & Agyare 2016).

5.2.1.3 Requests for a specific product

The high count of cases where a specific product was requested (n=962) might indicate a preference for certain antimicrobials based on perceived effectiveness, cost, or prior experiences. Alternatively, it could signify that the birds aren't necessarily ill, but antibiotics are being purchased for growth promotion or prophylactic purposes. This is a common practice, as shown in other studies conducted among poultry farmers in LMICs where antibiotics are used in sub-therapeutic doses to enhance production (Sasanya *et al.* 2005; Kariuki *et al.* 2023). This trend contributes to a selective pressure favoring resistance against these commonly requested antibiotics.

5.2.1.3 Types of drugs sold

Antibiotics, either alone or in combination with other drug types (antibiotic + anti-coccidial, antibiotic + vitamins), constitute almost two thirds of the drug sales in this study, highlighting their very central role in disease management strategies. This might indicate bacterial infections being especially common or a historical preference for antibiotics as the go-to treatment without knowledge of disease etiology.

The combination of antibiotics and vitamins is often administered to enhance the health of sick animals by supplementing with vitamins. However, this combination is also frequently utilized prophylactic or as a growth promoter. The shared use of antibiotics for both therapeutic as well as prophylactically treatment and growth promotion has been documented in various studies (Amaechi 2014; Oluwasile *et al.* 2014). Sub-therapeutic doses administered at low frequencies allow bacteria to adapt to the antibiotics, promoting resistance.

Of the anti-coccidial medications sold, 45% contained antibiotics, with 88% of those antibiotics comprising sulfonamides. These medications are frequently administered in the birds' feed or water at group level, often as a prophylactic measure (Abbas *et al.* 2011). This practice contributes to the development of resistance not only against antibiotics. There’s an emerging threat of resistance to the other substances commonly used in anti-coccidial medications, such as ionophores, nicarbazin, and amprolium.

All antibiotics should be treasured and in order to avoid AMR development and several actions could be helpful. Environmental management practices can limit bird exposure to coccidial oocysts. Integrated approaches combining immunity enhancement, vaccination, and non-chemical control methods could be used in order to avoid further development of AMR (Abbas *et al.* 2011).

5.2.1.4 Most common antibiotic substances sold

The most commonly used antibiotic substance by far is oxytetracycline. Tetra-cycline is used both alone and in combination with the macrolide erythromycin, as well as the aminoglycosides streptomycin and neomycin. The second most commonly used antibiotic is the macrolide tylosin, in combination with the tetracycline doxycycline. The dominance of this usage could be attributed to their cost, effectiveness, prior experiences or availability.

All the substances highlighted in Figure 9 as the most frequently purchased antibiotic substances by weight in the dataset are listed among the World Health Organization's critically important antimicrobials for human medicine (World

Health Organization 2019). Six of the 10 antimicrobial substances depicted in Figure 9 are highly important for human medicine, while 4 are classified as critically important (Table 2).

Table 2. The WHO classification of the most commonly purchased antibiotic substances based on their importance for human medicine.

Substance	**Antibiotic group**	**Classification of importance for human medicine by WHO**
Doxycycline	Tetracycline	Highly important
Erythromycin	Macrolide	Critically important
Neomycin	Aminoglycoside	Critically important
Oxytetracycline	Tetracycline	Highly important
Streptomycin	Aminoglycoside	Critically important
Sulfadiazine	Sulfonamide	Highly important
Sulfamethoxazole	Sulfonamide	Highly important
Sulfaquinoxaline	Sulfonamide	Highly important
Trimethoprim	Sulfonamide	Highly important
Tylosin	Macrolide	Critically important

All of these substances are broad spectrum antibiotics (Kanfer *et al.* 1998; Sköld 2000; Grossman 2016; Nowacka-Kozak *et al.* 2023) with varying efficacy against both gram-positive and gram-negative bacteria as well as protozoa. Half of the purchases in this study were made without consulting a veterinarian. Without veterinary consultation, diagnostics are not conducted, and bacterial cultures are not obtained to identify the causative bacteria. Identifying the bacteria would allow for a more targeted antibiotic use and lower the need for antibiotics with a broad spectrum, that promote AMR (Rao 1998).

While certain antibiotics are heavily relied upon, the moderate usage of other combinations suggests a diversified approach in some instances. The lower usage of certain antibiotics like amoxicillin, cloxacillin, and doxycycline might be due to various factors such as higher cost, limited availability, or perceived lower efficacy, but this diversification can present a lower risk of resistance development against less frequently used antimicrobials.

5.2.1.5 Composition of the antibiotics

The findings in the overall data, showing that 68% of the sold antibiotic products comprised multiple antibiotics, slightly exceed but remain comparable to the baseline study's proportion (65%). Only two of the top ten most commonly sold substances were sold individually. The other eight were combinations of several antibiotic substances. The high use of antibiotic combinations may be due to a perception of heightened therapeutic effects given their broad spectrum. The extensive usage of several antibiotics in combination, especially when not guided by specific diagnoses, is a key driver contributing to the emergence of multi-drug resistant bacteria. This overreliance might accelerate resistance development, compromising the effectiveness of these crucial medications (McGettigan *et al.* 2019).

There was a noteworthy difference between the counties confirmed by a Chi-square test, where county 1 had a higher number of multiple antibiotics (70%) than county 2 (61%). This difference suggests a divergence either in practices and preferences among agrovets, customer preferences or a difference in poultry health. Further investigation into the reasons behind this contrast could provide insights into the extent to which stakeholder preferences influence medication choices or the poultry disease prevalence in these geographical areas.

5.2.2 Challenges with analysis of the data

Several challenges were encountered during the data analysis. Primarily, the total purchases couldn't simply be added together due to varying pack sizes ranging from 10 g to 1000 g. Further, the precise quantity of active substances in the products remained unknown, which was an obstacle in accurately assesing the volume of antibiotics sold. Additionally, approximately 6% of the purchases consisted of injectables, which were not included in the analysis.

Even if the accurate volume of antibiotics could be calculated, drawing definitive conclusions without knowing the number of animals receiving the antibiotics and their individual doses is not possible. The U.S. Food and Drug Administration (2018) warns in its report that sales data on antibiotics should be used with caution. This data can be misinterpreted if factors such as the number of animals administered the drugs, the animals' weight (which may require higher doses per weight than in humans), and the understanding that sales data does not necessarily equate to actual usage are not considered (Food and Drug Administration 2018).

The intention was also to analyse the behaviour of different salespeople and it’s effect on the antimicrobial sales. Each agrovet attendant was identified by a unique code in the total dataset. However, 1600 purchases were attributed to a single code, suggesting that the agrovets did not use their individual codes consistently. Consequently, this hindered the comparison between different individuals, although it is a potential area for future investigation.

6. Conclusion

This study's findings align with worldwide concerns regarding the overuse and misuse of antibiotics. The reliance on antibiotics for treating sick animals, the prevalence of self-treatment among farmers, and how past experiences influence drug choices is concerning. The amount of critically important antimicrobials for human medicine among the most frequently bought substances emphasizes the urgency of using antimicrobials responsibly in veterinary practices.

These insights show the need for farmer education programs, aiming not only to promote the responsible use of antimicrobials but also to dispel misunderstandings and drive informed decision making.

Alongside these challenges lies a need for regulatory improvements. Strengthening rules and limiting sales to qualified personnel only emerge as important steps in protecting the agrovets to lessen the misuse of antimicrobials. The need for proper education for the agrovets selling the antibiotics is also important in order to strengthen them.

The study’s findings underscore the need for a multi-faceted plan consisting of data collection, education, guidelines, and technical resolutions. There is a call for cooperative work between policy makers, regulatory establishments, agrovets, veterinarians and farmers to create a road toward responsible microbial usage to safeguard animal as well as public health.

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Popular science summary

Antimicrobial resistance (AMR) might not grab the headlines, but it's a silent crisis to modern medicine. Imagine if infections, like those from a simple wound, become untreatable. This could be our reality in the future after less than 100 years of the first discovery of antibiotics. Antimicrobial medicine means medicine that can fight microorganisms responsible for infections such as bacteria, viruses, parasites, and fungi. Our most beloved antimicrobial is antibiotics targeting bacteria, but the misuse of them have fostered AMR where bacteria lose their sensitivity to the drugs.

Kenya's drug market is currently unregulated, which means that poultry farmers can buy drugs in the veterinary medicine stores called agrovets without the need for a prescription. An Information and Communication Technology (ICT) was developed and introduced to 14 agrovets working as salesmen of antimicrobial medicines in order to record their sales. 64% of the poultry purchases contained antibiotics, indicating a substantial reliance on antibiotics for treating poultry illnesses. This could indicate that antibiotics are the go-to treatment in many cases. Moreover, 68% of the antibiotic purchases were of medications composed of several classes of antibiotics.

The high use of antibiotic combinations may be due to a perception of heightened therapeutic effects given their broad spectrum; by combining them, they cover a large range of bacteria. However, this practice is contributing to the development of AMR. If the right bacteria causing the infection is identified, one single antibiotic class that covers that bacteria would be enough to treat the infection. All antibiotic substances in the ten most common antibiotic purchases are classified as highly or critically important for human medicine by the WHO, which speaks to how important monitoring this is.

The most common reference was a new prescription (33%) from a veterinarian, which is good news, but almost as many purchases were made with no reference (31%). In 34% of the purchases, a specific product was requested. This raise concerns that in many cases, the farmers haven’t been in contact with a veterinarian but made assumptions about the birds' diagnosis and what medication it needed on their own. People often tend to go with what they’re comfortable with and might go for a medication they used before and gotten good results from, even though the bird is now affected by another disease.

Interviews were conducted in each county with the agrovets recording their sales. They reported that the recording of their sales impacted their awareness of antibiotic usage and provided them with new insights. Several of them were shocked at the amount of antibiotics they were selling, and some of them had stopped eating eggs since they were not sure the farmers were taking the withdrawal period seriously.

They biggest problem they faced in their daily work was the ethical dilemma of being educated on responsible antimicrobial use, since most of the agrovets was veterinarians, but still running a business depending on the sales of them. They also experienced it being difficult to steer a buyer in another direction. Often, buyers come in with a specific product in mind, but even if the birds' symptoms don’t match that specific medicine, it’s hard to sell them another medication. If the agrovets refused to sell them that, the buyers could just go to the store next door.

Another problem is that most of the education the farmers get on antimicrobials is conducted by the pharmaceutical companies making them, in order to sell their medications. The agrovets wish for more education for the farmers on the responsible use of antimicrobials and other prophylactic manners that can prevent the birds from acquiring the disease in the first place.

The agrovets were not wishing for a requirement of a prescription in order to buy antibiotics, thinking it would affect their business too much. Instead, they wish that the Veterinary Medicines Directorate (VMD) would protect their profession by limiting sales to only educated people. They told about instances where the rules are not followed without any repercussions.

The findings in this study align with worldwide concerns regarding the overuse and misuse of antibiotics. To combat this silent crisis, further research and monitoring on this topic are needed in order to develop actions to help reduce the rising antimicrobial resistance.

Appendix 1

Consent form for Poultry farmers/ Agrovets engaged in the MAD-tech-AMR project.

Good day. My name is Linnea Lindfors, and I am a veterinary student from The Swedish University of Agricultural Sciences currently working for the International Research Institute (ILRI), in Nairobi. Thank you for finding time to meet with us today. We are grateful.

Our visit is part of the on-going poultry project that ILRI is implementing in Kenya (in collaboration with the Swedish University of Agricultural Sciences (Sweden), Makerere University (Uganda), and the University of Nairobi (Kenya)). The study was designed to have a baseline data collection activity (already completed), development of the project intervention (competed), testing/ piloting of the intervention and a final data collection exercise.

The pilot part of the intervention (agrovets, farms) started in May 2023 and is expected to continue to the end of the year. We are now in the middle of the pilot and would wish to assess how the project is progressing. A meeting with farmers and agrovets participating in the pilot has been arranged, to update them on the project progress, as well as gather their thoughts and experiences while interacting with the system. You have been invited given that you are actively participating in the project. We have developed a checklist which we will use to guide the discussions. There will be separate meetings for agrovet dealers and farmers. Your contribution during this session is important in evaluating the success of the project, and more importantly, in determining what needs to be done now, to make it easier for you to engage with the system. Concerns reported during the meeting will be addressed. The meeting will take about an hour to complete, during which we will take notes and record the discussion.

All what you share with us will be treated with utmost confidentiality and will only be used for project purposes. Please note that your participation in the study is voluntary, and you can withdraw at any time during the interview. There are no risks associated with your involvement in this study. Failing to participate in the project will not impact on your relationship with ILRI or UON, now or in the future. A summary of the results will be shared with you at the end of the project, together with other data that the project is collecting. Group results (and not your individual data) will be published in science journals, and anonymized data will be made open access. Your name will not appear anywhere in the publication. The study is funded by the Swedish International Development Cooperation Agency (Sida) through a partnership with African Academy of Sciences (AAS).

We are happy to respond to any questions that you might have.

We now request you to give your consent to participate in the study by indicating your name and signature in the space below.

- Contribute to the group discussions.
- Have a group picture taken.
- Have your voice recorded.

Date: __________________________

Name: _________________________

Signature: ______________________

We will leave a copy of this consent form with you in case you have any questions or wish to contact us after this meeting. Thank you so much for your time, and your continued collaboration with ILRI.

For more information about the study, please contact:

- ILRI IREC Secretariat: Telephone: +254 711 033 887; Email address: ILRIResearchcompliance@cgiar.org
- Florence Mutua, ILRI Scientist; Telephone: +254733546859; email: f.mutua@cgiar.org

Appendix 2

Questions for Agrovets

1. Is everyone here still involved in agrovet business? Is there any major change that has happened in your business since we started (which you think might have affected the data we are collecting).

2. What do you think of the MAD-tech-AMR project, so far? Which areas do you like most?

3. Which areas have you found challenging? Probe on these areas:
   a. *Using the tablets / navigating through the website*
   b. *Internet access*
   c. *Time involvement*
   d. *Visualizing the form – are you able to see the questions clearly*
   e. *Finding medicines in the system (how easy is it)*
   f. *Contacting the project team when there is an issue*

4. Have you recorded the sales in the system instantly or entered them all at the end of the day? What have you been doing to make sure that you do not forget to enter any data? What would you say the percent of sales that get recorded in our system?

5. Do sales vary with time, for example in the morning? Which days are busy for the agrovets?
6. The sales of antimicrobial substances by agrovets play a crucial role in the overall consumption of antimicrobials among poultry farmers. What is your perspective on this role? Do you feel that you have some kind of responsibility? How do you juggle this aspect while you still want to improve your business?
7. Is the problem of AMR something you consider in your daily work and do you adhere to any specific guidelines? Biggest concerns/problems you face in your daily work? *[would be good for the facilitator to explain what AMR is at the start, then let them respond]*

8. To what extent can you influence which drugs the farmers buy? Do you feel that you have enough information to advise them? If uncertain, who do you consult?
9. What influences the choice of which product to sell? Do the distributors play a part in it?
10. How do you respond when farmers request a specific medication? Can you easily redirect them if they for example describe parasitic symptoms for which antibiotics would be ineffective?
11. What are your thoughts on how the use of antimicrobial substances can be optimized and overuse/misuse reduced?
12. Besides using the system to record drug sales, has the system / intervention taught you anything? Have you applied this anyway, in your business/ elsewhere? Please tell us.

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