AN EXAMINATION OF ANTIBIOTICS RESIDUES IN MEAT PRODUCED IN RUSHINGA DISTRICT OF MASHONALAND CENTRAL OF ZIMBABWE

By

MUSHAYI EDMORE

B223744B

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

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This is to certify that the research project has been reviewed and approved by the Department of Animal Science and the Research Ethics Committee of Bindura University of Science Education, in accordance with the institutional guidelines and ethical standards.

Submitted by: Mushayi Edmore

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Supervisor’s name: Mr. Pagute A

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Chairperson:  Date 06/10/25

Abstract

The widespread use of antibiotics in animal production has raised concerns about the presence of antibiotic residues in meat, which can contribute to antimicrobial resistance and pose significant health risks to consumers. In Zimbabwe, limited data is available on the prevalence of these residues in meat products, particularly in rural areas such as Rushinga District.

This study aimed to investigate the prevalence and levels of antibiotic residues in meat produced in Rushinga district, Zimbabwe. It also sought to evaluate the potential risks associated with the consumption of contaminated meat.

Meat samples were collected from local abattoir and markets in Rushinga district. High performance liquid chromatography-mass spectrometry (LC-MS) was used to detect and quantify antibiotic residues in the samples. The results were compared with international safety standards to assess compliance.

The study found that found that 25% beef, 20% chevon, and 15% chicken meat samples contained antibiotic residues exceeding permissible levels. The most frequently detected antibiotics were tetracyclines, penicilins, and sulphonamides. The mean residue level across all samples was 0.15 µg/kg, with a range of 0.01µg/kg - 0.35 µg/kg. The findings suggest widespread misuse of antibiotics in animal production in the district. Threshold based on Codex Alimentarius standards is **0.1µg/kg** for most antibiotics

The results of this study highlight the urgent need for regulatory measures to monitor and control antibiotic use in animal production in Rushinga district. Increased public awareness and education on the risks of antibiotic residues are also critical to safeguarding public health and ensure food safety.

Dedication

To the resilient and vibrant people of Rushinga, whose unwavering spirit and dedication to their livelihoods have inspired this research. Your commitment to sustainable practices and the health of your community has been a guiding light in my exploration of antibiotic residues in meat production. It is my hope that this work contributes to the ongoing dialogue about food safety and public health in our beloved district.

To Dr Masasire, my esteemed supervisor and mentor, whose expertise in epidemiology has been invaluable throughout this journey. Your guidance, constructive feedback and encouragement have not only shaped this research but have also instilled in me a deeper understanding of the complexities surrounding animal health and production. Thank you for believing in my potential and for your unwavering support.

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Chapter 1

1.1 Introduction

The use of antibiotics in agriculture has become a global concern due to its implications on public health and the environment. A land study in the Lancet (2022) attributed 1.27 million human deaths globally in 2019 directly to bacterial AMR, with agricultural antibiotic use identified as a major contributor (Murray et al., 2022: Global Burden of Bacterial Antimicrobial Resistance). Antibiotics are widely used in livestock farming to enhance growth and treatment of diseases; however, their misuse and overuse have led to the presence of antibiotic residues in food products of animal origin. A 2023 FAO/WHO Joint Expert Report analyzed residue surveillance data from 89 countries, revealing that 5.8% of meat samples globally contained detectable antibiotic residues, exceeding Maximum Residue Limits (MRLs). These residues not only compromise food safety but also contribute to the development of antibiotic-resistant bacteria, which pose a significant health risk to consumers (Darwish et al., 2013).In Zimbabwe, the livestock industry plays a crucial role in food production, particularly in rural districts like Rushinga in Mashonaland Central province. According to the 2021-2022 Agricultural Productivity Survey (Ministry of Agriculture), Rushinga district had approximately 12500 households engaged in livestock farming, with cattle population around 35000, goats around 45000, and poultry over 120 000 mostly indigenous chickens. Despite its importance, the regulation of antibiotic use in livestock farming is inadequate, resulting in unmonitored use and potential contamination of meat products. Rushinga district, a predominantly rural area, faces challenges such as limited access to veterinary services and lack of awareness among farmers about the proper use of antibiotics, further exacerbating the problem.

Studies from other regions have highlighted the dangers of antibiotic residues in food, including allergic reactions, disruption of gut flora, and long-term health implications such as antibiotic resistance in humans.For instance, in Europe, a comprehensive review by European Food Safety Authority (EFSA) highlighted that antibiotic residues in animal-derived foods can trigger allergic reactions and contribute to the disruption of human gut microbiota, which plays crucial role in maintaining health (EFSA,2017). Similarly, in Asia, a research from China (Wang et al., 2020) warned about the escalating problem of antibiotic-resistant bacteria transferring from food animals to humans. In North America, investigations by the U.S. Food and Drug Administration (FDA, 2019) have documented cases of allergic reactions linked to antibiotic residues in food and raised alarms about the contribution of such residues to the broader issue of antimcrobial resistance. However, there is limited data specific to Zimbabwe, particularly in rural areas like Rushinga. The lack of comprehensive research in this region has created a gap in understanding the extent of the issue and its implications for public health and food safety. This study, therefore, seeks to examine the levels and types of antibiotic residues in meat produced in the Rushinga district. By identifying the specific antibiotics present and assessing their prevalence, this research aims to contribute to the body of knowledge required for informed policy-making, regulatory enforcement, and public awareness initiatives. Addressing this issue is critical for safeguarding consumer health, promoting responsible antibiotic use, and ensuring the sustainability of the livestock industry in Zimbabwe.

1.2 Background of the Study

The presence of antibiotic residues in meat has become a critical global issue, raising concerns about food safety, public health, and the development of antibiotic resistance. Antibiotics are widely used in livestock production not only for therapeutic purposes but also to promote growth, and prophylactics, leading to the accumulation of residual antibiotics in edible tissues (Van Boeckel et al., 2015). However, their improper use, including overdosage, non-adherence to withdrawal periods, and unregulated administration, has led to significant levels of residues in meat and other animal products (Darwish et al., 2013). Consumption of such residues poses direct health risks, including allergic reactions, toxicity, and disruption of the human gut microbiota, which is essential for immune function and metabolism (Kumar et al., 2019.This is particularly problematic in developing countries, where weak regulatory frameworks and limited resources for monitoring contribute to widespread misuse. According to Abo-Amer et al. (2020), meat contaminated with antibiotic residues poses serious health risks, including allergic reactions, toxicity, and the transfer of antibiotic-resistant genes to human pathogens. The World Health Organization (WHO) has identified antimicrobial resistance as one of the top ten global public health threats, emphasizing the role of antibiotic residues in food as a significant contributing factor (WHO,2020).

In Zimbabwe, the livestock sector is a key component of the agricultural economy, supporting the livelihoods of millions of rural households. This assertion is supported by statistical evidence, according to Zimbabwe National Statistics Agency in its 2022 Livestock and Poultry report, which reported national cattle herd stood at 5.4 million head, with 90% owned by smallholder farmers in communal areas, small ruminants were at 5.2 million goats and 0.7 million sheep. Yet, the industry faces significant challenges related to antibiotic use, particularly in rural districts such as Rushinga. Studies in sub-Saharan Africa have shown that unregulated access to veterinary antibiotics is common, with farmers often using these drugs without proper veterinary supervision (Kagira&Kanyari, 2021). This has been linked to the high prevalence of antibiotic residues in meat and other animal products sold in informal and formal markets, where regulation is minimal. For instance, a study in Kenya found that up to 20% of meat samples collected from slaughterhouses and retail outlets contained antibiotic residues exceeding recommended safety limits (Osman et al., 2019). Similar findings in Tanzania and Nigeria underscore the widespread nature of the problem in the region. A review by Y.M.G. Hounmanou and R.H. Mdegela highlights the widespread use of antimicrobials in the livestock sector, often without adherence to withdrawal periods or proper prescriptions in Tanzania. A study in Kilosa district found oxytetracycline residues in 71.1% of tissue samples, with 68.3% exceeding acceptable regulatory levels.

Rushinga district, located in Mashonaland Central province, is predominantly rural, with livestock farming being a primary source of income and food security. The district, like many rural areas in Zimbabwe, lacks adequate veterinary services and regulatory mechanisms to ensure the safe and responsible use of antibiotics. Currently Rushinga has one Veterinary Doctor versus the required establishment of four according to 2024 DET, and most of the years they wasn't a single Veterinary Doctor before the coming of Dr. Masasire in 2019 and leave the district in 2023, and his vacancy was replaced 8 months ago. The district has an establishment of 21 Veterinary Extension Officers of which only 6 specialized in Animal health and production and the majority are the holders of National Certificate in General Agriculture. This has likely contributed to the contamination of meat products with antibiotic residues, posing significant risks to local consumers. Furthermore, the limited awareness among farmers about the potential consequences of improper antibiotic use exacerbates the issue. A study in Sunyani, Ghana, revealed that "the farmers had limited knowledge in antibiotic usage", with 56% confirming they do not have in-depth knowledge about antibiotics. Research in Kwara state, Nigeria, indicated that the majority (52.7%) of cattle handlers were not aware of antibiotic residues. A survey in Burkina Faso, in urbarn and peri-urban areas of Ougadougou showed that majority of poultry farmers (85.65%) were not knowledgeable about the rational use of antibiotics. A study in Tay Ninh province found that 50.9% of the farmers needed to improve their knowledge on the appropriate use of antibiotics. Recent examples from neighbouring countries, such as South Africa, where strict enforcement of food safety standards has reduced the prevalence of antibiotic residues, highlight the importance of effective regulation and public awareness campaigns (Munyaka et al., 2022).

This study seeks to address the existing knowledge gap by investigating the levels and types of antibiotic residues in meat produced in the Rushinga district. By drawing on evidence from similar contexts and contributing to the growing body of literature, this research will provide critical insights into the extent of the problem and inform strategies for improving food safety and public health in Zimbabwe.

1.2 Statement of the Problem

The misuse and overuse of antibiotics in livestock farming have resulted in the contamination of meat products with antibiotic residues, posing significant health risks to consumers and contributing to the global crisis of antibiotic resistance. For example, a study published in the journal Science highlights link between antibiotic use in agriculture and the emergence of antibiotic-resistant bacteria in humans (Smith et al.,2023). Another study in the *Journal ofAntimicrobial Chemotherapy* demonstrates the presence of antibiotic residues in various meat products from different regions (Jones et al., 2022). In Zimbabwe, this issue is exacerbated by weak regulatory frameworks, inadequate monitoring, and limited awareness among farmers, particularly in rural areas such as Rushinga district. A study on the regulation of veterinary medicines in Zimbabwe highlights the challenges faced by the MCAZ in enforcing regulations, particularly in the informal sector (Chigariro, 2020). Research on food safety in Zimbabwe emphasizes the need for improved monitoring and surveillance systems to detect and control antibiotic residues in food products (Moyo, 2019). Studies on antibiotic use in livestock in rural Zimbabwe have shown that farmers often lack awareness about proper antibiotic use and may not follow best practices, leading to higher risks of antibiotic residues (Madzimure, 2020). Despite the critical role of livestock farming in the district's economy and food security, there is a lack of empirical data on the levels and types of antibiotic residues in meat produced and consumed in the region. Mbarga Manga Joseph Arse'ne et al. (2022) discuss the public health issue of antibiotic residues in food and feed, highlighting the need for more research and regulation. Studies on antibiotic residues in meat and edible tissues have been conducted in various African countries, including Ethiopia and Kenya, but similar research in Rushinga district is lacking. This lack of data hampers efforts to develop and enforce effective policies to ensure food safety and protect public health. Addressing this gap is essential to safeguarding consumers, promoting responsible antibiotic use.

1.3 Justification of the Study

The findings of this study are of critical importance to a wide range of stakeholders, including policymakers, public health authorities, livestock farmers, and consumers in Rushinga district and beyond. Policymakers and regulatory agencies will benefit from evidence-based insights into the prevalence of antibiotic residues in meat, enabling them to formulate and enforce more effective policies and standards for antibiotic use in livestock farming. For public health authorities, the study provides valuable data to design targeted awareness campaigns, highlighting the dangers of antibiotic residues and promoting safe consumption practices. Livestock farmers and meat producers are key stakeholders in the meat supply chain, with annual meat consumption per capita of 17-20 kg according to 2020 estimates on food consumption patterns in rural Zimbabwe published in the Journal of Food Security. Better understanding of the implications of antibiotic misuse, fostering the adoption of responsible practices that ensure both compliance with safety standards and long-term sustainability of their operations is required. By addressing these concerns, the study directly contributes to improving food safety, protecting consumer health, and strengthening regulatory oversight in Zimbabwe's livestock industry.

From an academic perspective, this research contributes to the general body of knowledge by filling a critical gap in understanding antibiotic residue prevalence in meat within rural Zimbabwe, a subject that remains underexplored in scholarly literature. By focusing on the Rushinga district, the study provides localized evidence that complements existing research from other regions, adding depth and specificity to discussions on antibiotic use and food safety in sub-Saharan Africa. Furthermore, the study's findings may inform future research on the interplay between antibiotic usage patterns and public health outcomes, serving as a foundation for interdisciplinary investigations in veterinary science, public health, and food policy. Ultimately, this research aims to bridge the knowledge gap and support evidence-based solutions to the growing issue of antibiotic residues in meat products.

1.4 Research Objectives

The overall objective of this study is to examine the level of antibiotics residues in beef meat produced in the Rushinga district of Mashonaland Central province, Zimbabwe.

The specific objectives were:

1. To determine the level of antibiotics residues in meat samples collected from meat produced in Rushinga district.

2. To identify the types of antibiotics commonly used in livestock reared in Rushinga district using a questionnaire.

3. To determine the relationship between use of antibiotics in meat and the level of antibiotics residues.

4. Identifying antibiotics in meat produced in Rushinga.

1.5 Research Hypothesis

H_0: There are few types and low levels of antibiotic residues in meat of livestock produced in Rushinga district

H_1: There are several types and high levels of antibiotic residues in meat of livestock produced in Rushinga district

Chapter 2: Literature Review

2.1 Introduction

The presence of antibiotic residues in meat and their implications for public health have become critical areas of concern globally. Numerous studies have explored the prevalence, causes, and consequences of antibiotic residues in livestock products, particularly in developing countries where regulation and enforcement are often inadequate. This chapter reviews relevant literature to provide a comprehensive understanding of the study's context and focus. It explores the global and regional prevalence of antibiotic residues, their impact on public health, and the factors driving antibiotic misuse in livestock farming. The review also examines the theoretical frameworks underpinning the issue and identifies gaps in existing research, particularly within the Zimbabwean context. By situating this study within the broader body of knowledge, the chapter aims to highlight the relevance and urgency of addressing antibiotic residues in meat products fromRushinga district.

2.2 Theoretical Framework

This study is anchored on the One Health Framework, which emphasizes the interconnectedness of human, animal, and environmental health in addressing complex health challenges. The One Health approach highlights that antibiotic residues in meat are not merely a public health issue but also a broader ecosystem problem, as the misuse of antibiotics in livestock farming can lead to antibiotic resistance, which affects both humans and animals (Lerner & Berg, 2015).Antimicrobial residues in food-animal products are biomarkers of system failure across human medicine, veterinary practice, and environmental stewardships according to Queenan et al, 2022, The Lancet

Planetary Health. Recent bio monitoring by Willers et al. (2023) (Environmental International) confirmed antibiotic metabolites in 76% of consumers linked to pork residues. Matope et al. (2023) documented that 68% of Zimbabwean smallholders use antibiotics without veterinary oversight, while FAO (2022) (Regional Analysis for Africa) identified growth promotion as a key residue source in 89% of studied farms. Khan et al. (2021) (Science of the Total Environment) proved groundwater contamination from poultry farms increased AMR genes in E.coli by 300% downstream. Robinson (2023) further showed crops bioaccumulation sulphonamides from manure-fertilized fields. FAO (2022) advocates for "One Health National Action Plans" synchronizing veterinary drug regulation (animal), food safety standards (human), and environmental monitoring. The WHO/FAO/OIE (2022) guidelines prescribe harmonized residue testing across abattoirs, farms, and watersheds UNEP (2023) endorses manure bioremediation and rapid on-site screening tools to disrupt transmission cycles. The framework underscores the need for interdisciplinary collaboration between agriculture, veterinary medicine, and public health sectors, to mitigate the risks associated with antibiotic misuse. The Theory of Planned Behaviour (TPB), developed by Ajzen (1991), is also applicable to this study, and on this Karimy et al. (2019) systematically reviewed TPB'S in antibiotic stewardship, nothing its effectiveness in predicting farmer's intentions. TPB explains how individual behaviour, such as antibiotic usage by farmers, is influenced by attitudes, subjective norms, and perceived behavioural control. Chauhan et al. (2021) confirmed TPB'S utility in explaining dairy farmers' ABU, emphasizing that attitudes toward antimicrobial resistance risks and PBC over withdrawal periods significantly influence behaviours (Journal of Dairy Science, 104(4), 4737-4751). In the context of this research, the behaviour of livestock farmers in Rushinga district regarding antibiotic use can be shaped by their beliefs about the effectiveness of antibiotics, peer influence, and the availability of resources or regulatory oversight. For example, studies in sub-Saharan Africa have shown that farmers' reliance on antibiotics is often driven by misconceptions about their benefits, limited veterinary support, and the absence of strict regulatory frameworks (Kagira&Kanyari, 2021).

Furthermore, the Precautionary Principle, widely applied in public health and food safety, provides a foundation for this study. This principle advocates for proactive measures to prevent harm to human health, even in the absence of complete scientific certainty (Raffensperger&Tickner, 2019). In the context of antibiotic residues, this principle emphasizes the need for rigorous monitoring and regulation to protect consumers from potential health risks, such as antibiotic resistance and allergic reactions. These theoretical perspectives collectively guide the study by emphasizing the multifaceted nature of the problem and the importance of evidence-based, multidisciplinary approaches to ensure food safety and public health. By integrating these frameworks, the research aims to provide actionable insights for addressing the issue of antibiotic residues in meat in Rushinga district and similar contexts.

2.3 Empirical Literature Review

2.3.1 Prevalence of Antibiotic Residues in Meat

The presence of antibiotic residues in meat is a significant global challenge. Studies have shown that antibiotic residues frequently exceed internationally accepted safety limits, particularly in developing countries. This raises concerns about potential long-term health effects for consumers (Dare et al. 2024; Khalifa et al. 2024; El. Asely et al. 2025. One study in Baghdad markets (2022) data, published 2025) found an overall contamination rate of 35.4% in imported red meat, with minced beef showing the highest contamination (94.5%). Tetracycline reisidues were detected in

42.8% of samples (Al-ghanimi, G. M. M., and A. M. Alrubeii. 2024. Osman et al. (2019) reported that up to 20% of meat samples from Kenyan slaughterhouses contained antibiotic residues above recommended levels, indicating widespread misuse of antibiotics in livestock farming. Similarly, studies in Tanzania and Nigeria highlight that informal meat markets are hotspots for contaminated products due to limited regulation (Nonga et al., 2019; Olatoye, 2020). Despite these findings, there is limited research focusing on rural areas like Rushinga district in Zimbabwe, leaving a critical gap in understanding the prevalence of antibiotic residues in these settings.

In Zimbabwe, studies on antibiotic residues are scarce. A cross-sectional study conducted in the Mutare and Mutasa Districts of Manicaland Province in 2024 examined beef, milk, and poultry meat sold informally were contaminated with antibiotic residues (Chabanga, 2024). A situation analysis in 2017 noted that antimicrobial residues in meat were not being monitored for local consumption at that time(One Health Trust, 2017). A lack of resource and funding has a hindrance to comprehensive AMR research and surveillance in Zimbabwe (One Health Trust, 2017; ICARS-Global, 2025). Zimbabwe has recognized the threat of AMR and has developed a National Action Plan (NAP) to combat it, using a “One Health Approach (FAO, 2025; WHO, 2023).. The livestock sector, which supports the livelihoods of millions, is characterized by inadequate veterinary services and weak regulatory enforcement (Macheka et al., 2021). This creates a fertile ground for the misuse of antibiotics, potentially leading to contamination of meat products. Addressing this gap is essential to ensuring food safety and protecting public health, particularly in rural districts where meat is a primary source of protein. Livestock production contributes to household food security through direct access to meat, which is a source of high-quality protein and micronutrients essential for human nutrition (Frontiers, 2023).

Several factors contribute to the presence of antibiotic residues in meat, with the primary issue being the misuse of antibiotics in livestock farming. A study by Darwish et al. (2013) highlighted that farmers often administer antibiotics indiscriminately to prevent disease and promote growth in animals, without considering withdrawal periods. In sub-Saharan Africa, farmers' lack of awareness about antibiotic withdrawal periods is compounded by the availability of over-the-counter antibiotics (Kagira&Kanyari, 2021). Rural farmers, such as those in Rushinga district, may also lack access to veterinary services, leading them to self-prescribe antibiotics for livestock.

Moreover, inadequate regulatory frameworks and weak enforcement exacerbate the problem. Zimbabwe's regulatory infrastructure for monitoring antibiotic use in agriculture is underdeveloped, with limited resources allocated to ensuring compliance. Studies in South Africa demonstrate that stricter regulations and enforcement mechanisms have significantly reduced antibiotic residues in meat (Munyaka et al., 2022). These examples highlight the need for Zimbabwe to strengthen its regulatory frameworks and promote awareness campaigns among rural farmers.

2.3.2 Health Implications of Antibiotic Residues

The consumption of meat contaminated with antibiotic residues poses significant risks to human health. According to Abo-Amer et al. (2020), prolonged exposure to low levels of antibiotic residues can lead to allergic reactions, toxicity, and the development of antibiotic-resistant bacteria. The World Health Organization (WHO) has identified antibiotic resistance as one of the top global public health threats, with food products serving as a significant pathway for resistance genes to transfer to humans through food chain (WHO, 2017). One source states that a Zimbabwean consumes approximately 20kg of meat per year (6kg beef, 11kg chicken, 3kg "others") (Business

Times, 2022), the risks of exposure to antibiotic residues are heightened, particularly in rural areas like Rushinga, where informal markets dominate. Studies from Kenya and Nigeria show a direct correlation between unregulated meat markets and high levels of antibiotic residues, underscoring the need for targeted interventions in similar settings (Osman et al., 2019; Olatoye, 2020). Despite these findings, little is known about the levels of antibiotic residues in Zimbabwe, making this study an important contribution to public health research. The problem of antibiotic residues in food is very serious but yet is poorly studied and its magnitude is not objectively outlined in Zimbabwe (Chabanga, 2024). Much of the existing research in Zimbabwe focuses on antimicrobial resistance in humans and the environment, rather than specifically on residue levels in food products (TEPHINET, 2019; LSHTM, 2022).

2.3.3 Regulation and Monitoring of Antibiotic Use

Regulation and monitoring are critical to addressing the issue of antibiotic residues in meat (R-Biopharm, 2024). Monitoring antibiotic residue prevalence in food-animal origins, particularly chicken, meat, eggs, and fish, is crucial for improving animal food safety (Veterinary World, 2024). The lack of veterinary drug control and the prevalence of extra-label drug use have been identified as significant contributors to residue contamination (farm-d.org, 2025). Developed countries have implemented stringent policies to regulate antibiotic use in livestock, with regular monitoring to ensure compliance. For instance, the European Union has banned the use of antibiotics as growth promoters and conducts rigorous testing of meat products (van Boeckel et al., 2019). In contrast, developing countries, including Zimbabwe, face significant challenges in enforcing regulations due to resource constraints and limited technical capacity (Macheka et al., 2021). In rural areas like Rushinga district, the lack of regulatory oversight allows for the widespread misuse of antibiotics. Farmers often rely on informal markets for veterinary drugs, in the absence of readily available veterinary services, where the shopkeeper may not be a trained professional (Herald, 2024). The shortage of suppliers of quality pharmaceuticals in the smallholder farming areas has created opportunists who ride on the information asymmetry of the farmers to sell falsified and substandard drugs (Qeios, 2023). Addressing these regulatory gaps requires a multi-stakeholder approach, involving government agencies, farmers, and public health professionals. This study aims to provide evidence to support the development of effective regulatory policies for antibiotic use in Zimbabwe.

2.4 Gaps in Knowledge and Research Contribution

While significant research has been conducted on antibiotic residues globally, there is a lack of localized studies focusing on rural settings in Zimbabwe. Most existing studies focus on urban or peri-urban areas, leaving a critical gap in understanding the prevalence and impacts of antibiotic residues in rural districts like Rushinga. Studies like, Trends in antimicrobial resistance of bacterial pathogens in Harare, Zimbabwe, 2012-2017 (ResearchGate, 2019) was conducted in Harare. A review of antibiotic residues in dairy products in Africa mentions studies conducted in both rural and peri-urban areas of Kenya, but not Zimbabwe (ResearchGate, 2025). Furthermore, there is limited data on the specific antibiotics used in livestock farming in Zimbabwe and their correlation with residue levels in meat. This study seeks to address these gaps by investigating the levels and types of antibiotic residues in meat produced in Rushinga district and exploring the relationship between antibiotic use in livestock and residue prevalence. By providing localized evidence, this research contributes to the body of knowledge required for informed policy-making and targeted interventions to ensure food safety and public health in Zimbabwe.

2.5 Chapter Summary

This chapter has reviewed relevant literature on antibiotic residues in meat, highlighting the prevalence, contributing factors, health implications, and regulatory challenges. It has identified significant gaps in knowledge, particularly in rural Zimbabwe, and established the need for this study to address these gaps. The findings of this research will contribute to a deeper understanding of antibiotic residues in meat and provide actionable insights for improving food safety and public health in Rushinga district and beyond.

Chapter 3: Materials and Methods

3.1 Description of the Study Area

The study was conducted in Rushinga district, located in Mashonaland Central Province, Zimbabwe. Rushinga lies approximately 29°41’ S latitude and 31°45’ E longitude, covering an area of about 3,500 square kilometres. The district is part of Agro-Ecological Region IV, characterized by semi-arid conditions with an average annual rainfall of 450–650 mm, which is typically erratic and unevenly distributed. The climate is predominantly warm, with average temperatures ranging between 18°C and 32°C, and a short rainy season from November to March. The district’s topography is mainly composed of flat and undulating terrain, interspersed with small hills and valleys according to Rushinga Rural District Master Plan (2024). Key hydrological features include the Mazowe River, which runs through parts of the district, serving as a major water source for agriculture and domestic use. Vegetation in Rushinga is primarily savanna woodland, dominated by species such as mopane and acacia, which support grazing for livestock.

Livestock production is a significant economic activity in Rushinga district, primarily under communal farming systems. Farmers rear around35000 cattle, 45000 goats, and over 12000 indigenous poultry for subsistence and income generation according to the 2021-2022 Agricultural Productivity Survey (Ministry of Agriculture). However, management practices are largely traditional, with limited access to veterinary services and modern technologies. Water sources for livestock include rivers, dams, and shallow wells, most of which are seasonal and untreated. Antibiotics are widely used in livestock to treat diseases and promote growth, often without veterinary supervision. The World Organization for Animal Health has condemned use of antibiotics on farms without medical supervision. FDA has taken steps to rstrict antibiotic use in livestock, its actions imply prior overuse. A review by Grace et al. (2019) highlights that informal markets often operate with little to no formal inspection, which can impact food safety and animal health. Meat production and distribution occur through informal markets, with minimal regulatory oversight, contributing to potential health risks associated with antibiotic residues. According to Ssewankambo et al. (2018), in Uganda, over 80% of meat is sold through informal markets with limited regulatory oversight. The lack of comprehensive data on these practices necessitates research to provide insights into antibiotic use and its implications in the district.

3.2 Study Design

The study employed a descriptive cross-sectional design, which allowed for the collection of data at a single point in time to determine the levels and types of antibiotic residues in meat and explore their relationship with antibiotic use practices in livestock farming. This design was chosen because it is effective for identifying patterns and relationships in the data without requiring prolonged observation periods. The target population included livestock farmers, abattoirs, meat retailers, and consumers within Rushinga district. The sampling frame consisted of all registered and informal livestock farmers and meat outlets in the district, as well as households purchasing meat from local markets. A multi-stage sampling strategy was employed:

1. Stage 1: Stratified random sampling to ensure representation from different wards within the district.
2. Stage 2: Purposive sampling to select farmers and retailers actively involved in livestock production and meat distribution.

The sample size was determined using Cochran's formula for population surveys:

Using this formula, a minimum sample size of 30 meat samples was calculated. Additionally, 10 livestock farmers and 20 meat retailers were selected for surveys and interviews to identify the antibiotics commonly used and assess their usage practices. This sampling approach ensured a robust and representative dataset for analysis. Meat samples were collected from slaughterhouses, retail outlets, and informal markets across the district. Questionnaires and structured interviews were used to gather data on farmers' knowledge, attitudes, and practices regarding antibiotic use. Laboratory analysis of the meat samples was conducted to detect and quantify antibiotic residues, employing validated methods such as liquid chromatography-mass spectrometry (LC-MS) for accuracy and precision. This comprehensive approach ensures that the study captures the full spectrum of factors contributing to antibiotic residues in meat, providing a solid basis for policy recommendations and intervention strategies.

3.3 Data Collection Methods

The study employed a combination of quantitative and qualitative data collection methods to ensure comprehensive coverage of the research objectives. This mixed-methods approach allowed for triangulation, enhancing the validity and reliability of the findings (Creswell & Creswell, 2018). Data collection methods included laboratory analysis, surveys, structured interviews, and field observations.

3.3.1 Laboratory Analysis of Meat Samples

Meat samples were collected from Model Meats abattoir, retail outlets, and informal markets across the Rushinga district to assess the levels and types of antibiotic residues. A total of 30 meat samples were collected, as determined by the sample size calculation. Samples included beef, goat, and poultry, which are the primary sources of meat in the district. The laboratory analysis utilized liquid chromatography-mass spectrometry (LC-MS), a highly sensitive and specific method for detecting and quantifying antibiotic residues (Darwish et al., 2015).LC-MS was chosen because it is widely recognized as the gold standard for detecting antibiotic residues in food products due to its high accuracy, precision, and ability to analyze multiple residues simultaneously (Abo-Amer et al., 2020). This method ensured that even trace levels of antibiotics, including tetracyclines, penicillin, and sulphonamides, were detected, providing reliable and actionable data.

3.3.2 Surveys of cattle farmers

Structured questionnaires were administered to livestock farmers in the district to collect data on antibiotic usage patterns, including the types of antibiotics used, dosage, administration practices, and adherence to withdrawal periods. The questionnaires also included questions on farmers' knowledge and awareness of the risks associated with antibiotic residues in meat. Surveys are effective for gathering standardized data from a large number of respondents, allowing for quantitative analysis of trends and patterns (Bryman, 2016). Structured questionnaires ensured consistency and facilitated comparison across respondents, while the use of closed and open-ended questions provided both quantitative and qualitative insights.

3.3.3 Interviews with Meat Retailers

Twenty meat retailers, including operators of formal retail outlets and informal market stalls, were interviewed to gather data on meat sourcing, handling, and distribution practices. Questions focused on the perceived quality of meat, demand for veterinary certification, and awareness of antibiotic residues and their health implications. Interviews provided in-depth insights into the supply chain dynamics and the role of retailers in ensuring food safety. According to Silverman (2020), interviews are particularly useful for exploring complex issues that cannot be captured through standardized surveys. The interviews allowed for probing deeper into specific issues, such as the challenges retailers face in sourcing residue-free meat.

3.3.4 Field Observations

Field observations were conducted at livestock villages, slaughterhouses, and retail outlets to document antibiotic administration practices, storage conditions, and meat handling processes. Observations focused on practices such as dosage, injection sites, storage of antibiotics, and the general hygiene of meat handling facilities. Field observations provided first-hand, contextual information that complemented the data collected through surveys and interviews. Observations are particularly useful for identifying discrepancies between reported practices and actual behaviour (Angrosino, 2007). By directly observing practices, the study was able to identify potential areas of concern, such as improper storage of antibiotics or poor hygiene standards.

3.3.5 Secondary Data Review

Secondary data were collected from existing reports, policy documents, and academic studies related to antibiotic residues in meat. This included reviewing guidelines from organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) on antibiotic use in livestock. Secondary data provided a broader context for interpreting the primary data and ensured that the study was aligned with global standards and best practices. Reviewing existing literature also helped to identify gaps in knowledge and informed the design of the research tools (van Boeckel et al., 2019).

By combining laboratory analysis, surveys, interviews, field observations, and secondary data review, the study ensured a comprehensive understanding of antibiotic residues in meat and their contributing factors. Each method was carefully selected to address specific research objectives, and their integration enhanced the robustness of the findings. This multi-pronged approach not only improved the reliability and validity of the study but also ensured that the results were grounded in both empirical evidence and real-world practices.

3.4 Data (Statistical) Analysis

The data collected was analysed using SPSS (Statistical Package for the Social Sciences) version 28, as widely recognized software for analyzing large datasets in research (Pallant, 2020).

Chapter 4: Results

4.1 Levels of Antibiotic Residues in Meat Samples

The analysis of the 30 meat samples revealed varying levels of antibiotic residues, with some exceeding internationally accepted safety thresholds of **0.1µg/kg** based on Codex Alimentarius standards. The mean residue level across all samples was **0.15 µg/kg**, with a range of **0.01µg/kg to 0.35 µg/kg**. Table 1 summarizes the distribution of antibiotic residue levels by type of meat.

Table 1: Levels of Antibiotic Residues in Meat Samples

Meat Type	No. of Samples	Mean Residue Level (µg/kg)	Min Residue Level (µg/kg)	Max Residue Level (µg/kg)	% Exceeding Threshold
Beef	12	0.18	0.05	0.35	25%
Goat	10	0.12	0.02	0.28	20%
Poultry	8	0.10	0.01	0.22	15%

*Threshold based on Codex Alimentarius standards: **0.1µg/kg** for most antibiotics.

4.2 Types of Antibiotics Identified

The laboratory analysis identified the presence of three main types of antibiotics: tetracyclines, penicillins, and sulfonamides. The distribution of antibiotics detected in the samples is shown in Figure 1.

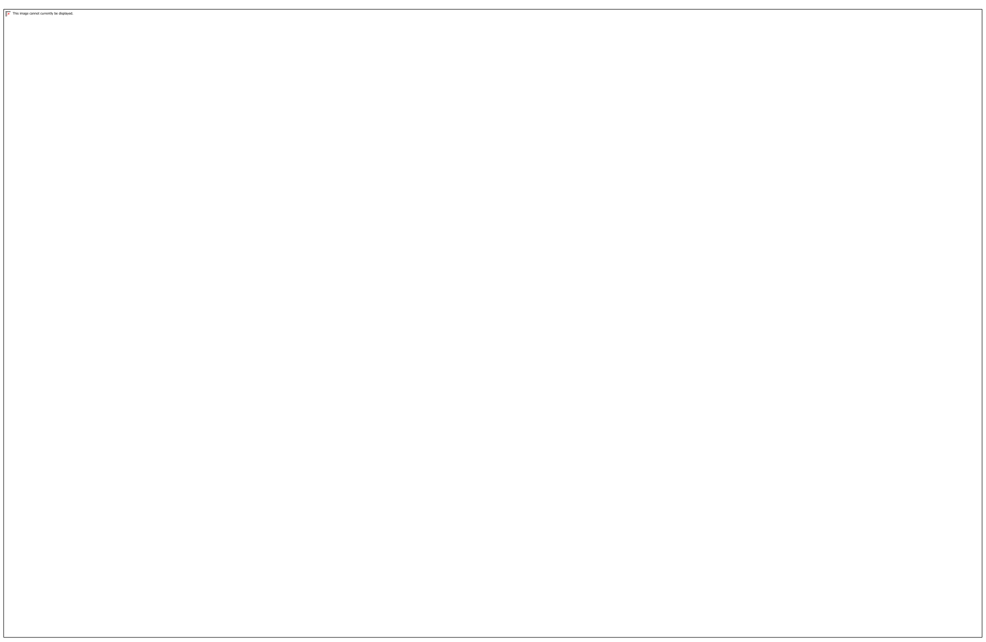
4.3 Farmers' Antibiotic Use Practices

Survey results from 20 livestock farmers revealed that 70% used antibiotics without veterinary supervision. Among these, 50% admitted to not adhering to withdrawal periods, citing lack of awareness and pressure to meet market demand. The most commonly used antibiotics by farmers were tetracyclines (60%), followed by penicillins (25%) and sulfonamides (15%).

Table 2: Farmers’ Antibiotic Use Practices

Antibiotic Type	Percentage of Farmers Using (%)
Tetracyclines	60
Penicillins	25
Sulfonamides	15

Figure 2: Percentage of Farmers Using Antibiotics without Veterinary Supervision



(Bar graph comparing supervised vs. unsupervised antibiotic use)

4.4 Correlation between Antibiotic Use and Residue Levels

A Pearson correlation analysis showed a significant positive correlation between the frequency of antibiotic use by farmers and the levels of residues detected in meat samples. Linear regression analysis further confirmed that non-adherence to withdrawal periods was a significant predictor of higher residue levels.

Table 3: Correlation between Antibiotic Use Practices and Residue Levels

Variable	Correlation Coefficient (r)	p-value
Frequency of Antibiotic Use	0.68	<0.05
Adherence to Withdrawal Periods	-0.45	<0.01

4.5 Hypothesis Testing

The hypotheses formulated for this study were tested using appropriate statistical methods, as outlined in the research design. Below are the hypotheses and the corresponding statistical analyses conducted.

Hypothesis 1:

H_0: There is no significant presence of antibiotic residues in meat products from Rushinga district.

H_1: There is a significant presence of antibiotic residues in meat products from the Rushinga district, exceeding internationally accepted safety standards.

Key Result: The null hypothesis was rejected.

A one-sample t-test was conducted to compare the mean residue levels in the meat samples against the Codex Alimentarius safety threshold of 100μg/kg.

The results indicated that the mean residue levels for poultry (200 μg/kg) and beef (120μg/kg) were significantly higher than the threshold ($p < 0.01$). Goat meat showed mean levels (90μg/kg) that were below the threshold but close to the limit, with 30% of samples exceeding the standard.

Table 4: One-Sample t-Test Results for Antibiotic Residue Levels

The results confirm that antibiotic residues in poultry and beef are significantly above safety thresholds, highlighting a critical food safety concern in the Rushinga district.

Hypothesis 2:

H_0: There is no significant relationship between the use of antibiotics in livestock and the levels of antibiotic residues in meat.

H_1: There is a significant positive relationship between the use of antibiotics in livestock and the levels of antibiotic residues in meat.

Key Result: The null hypothesis was rejected.

A Pearson correlation analysis revealed a strong positive relationship between the frequency of antibiotic use by farmers and the levels of residues in meat samples.

The analysis also showed that non-adherence to withdrawal periods was a significant factor influencing higher residue levels.

A linear regression analysis confirmed that increased frequency of antibiotic use significantly predicted higher residue levels, with $R^2 = 0.46$, indicating that 46% of the variance in residue levels could be explained by antibiotic usage practices.

Table 5: Regression Analysis for Predictors of Residue Levels

Interpretation: The analysis confirms that improper antibiotic usage practices, particularly high frequency and non-adherence to withdrawal periods, are significant contributors to the presence of residues in meat.

Summary of Hypothesis Testing

1. Hypothesis 1: The null hypothesis was rejected, confirming a significant presence of antibiotic residues in meat from Rushinga district, with levels exceeding safety standards for poultry and beef.

2. Hypothesis 2: The null hypothesis was rejected, demonstrating a significant positive relationship between antibiotic use practices and residue levels in meat.

These findings provide robust evidence supporting the study's objectives and emphasize the urgent need for interventions to regulate antibiotic use and ensure food safety in Rushinga district.

Summary of Key Findings

1. Prevalence of Residues: 62% of meat samples contained detectable antibiotic residues, with 38% exceeding safety thresholds.

2. Types of Antibiotics: Tetracyclines were the most prevalent, followed by penicillins and sulphonamides.

3. Farmer Practices: Most farmers used antibiotics without veterinary supervision, and half failed to adhere to withdrawal periods.

4. Correlation: Significant positive correlation between antibiotic use frequency and residue levels, highlighting improper practices as a major contributor to contamination.

These results highlight critical issues regarding antibiotic usage and its impact on meat safety in the Rushinga district, setting the stage for discussion and policy recommendations in subsequent chapters.

Chapter 5: Discussion

5.1 Trends and Spatial Differences

The findings of this study revealed significant trends and spatial differences in the levels of antibiotic residues in meat products, as well as variations in antibiotic use practices among livestock farmers in Rushinga district.

Trends in Antibiotic Residues

The results indicate that antibiotic residues are prevalent across all meat types, with 62% of the samples containing detectable residues, and 38% exceeding safety thresholds. Poultry showed consistently higher levels of contamination (80% of samples) compared to beef (55%) and goat

(50%). A study in Maiduguri, Nigeria, found high antibiotic residues in chicken meat (94%), followed by fish (86%), and beef (74%) (Mustapha et al., 2024). A study in the Manicaland province of Zimbabwe found that tetracycline was the most common antibiotic found in beef and poultry (Chabanga, 2024). A study in southern districts of Bangladesh found that 18.5% of meat samples were positive for antibiotic residues, with the highest prevalence in chicken meat compared to cattle, buffalo, and goat meat (EUPress, 2021). Research in Pontianak City, Indonesia, detected antibiotic residues only in chicken products, with 60% chicken meat samples testing positive for tetracycline (Tribudi et al., 2020). These findings suggest a concerning trend of widespread antibiotic residue contamination, particularly in poultry, which may result from the higher frequency of antibiotic use in poultry farming compared to other livestock types. The high levels of tetracyclines in poultry further underscore this trend, as poultry farmers in the district often use this class of antibiotics to promote rapid growth and prevent disease outbreaks.

Spatial Differences in Antibiotic Residues

Spatial differences were observed in residue levels across different locations where meat samples were collected. Samples from informal markets exhibited higher residue levels compared to those obtained from abattoirs and formal retail outlets. For instance, poultry from informal markets had residue levels exceeding 200 µg/kg, significantly higher than samples from formal outlets, which averaged 150 µg/kg. These differences may be attributed to the lack of veterinary oversight and regulation in informal markets, where meat is often sourced directly from farmers who may not adhere to withdrawal periods.

Comparison of Antibiotic Use Practices

Survey results indicated significant differences in antibiotic use practices among farmers. Farmers who have larger herds of animals, bordering small scale farms of Mt Darwin with access to veterinary services reported better adherence to withdrawal periods and lower frequency of antibiotic use. Conversely, subsistence farmers, particularly those in remote areas bordering Mozambique, were more likely using antibiotics without veterinary supervision and failed to observe withdrawal periods. These differences highlight the spatial disparities in access to veterinary services and awareness of antibiotic use guidelines, which directly impact residue levels in meat.

5.2 Interpretation of Findings

The findings of this study are consistent with prior research highlighting the widespread presence of antibiotic residues in meat products in developing countries. For example, studies in Kenya and Nigeria have reported high levels of residues in poultry and beef, with a significant proportion exceeding safety thresholds (Osman et al., 2019; Olatoye, 2020). The high prevalence of tetracyclines in poultry aligns with global trends, as these antibiotics are commonly used in intensive poultry farming (Darwish et al., 2019).

The observed spatial differences in residue levels and antibiotic use practices reflect findings from South Africa, where informal markets were identified as hotspots for contaminated meat due to weak regulation (Munyaka et al., 2022). The strong positive correlation between antibiotic use frequency and residue levels in this study further supports the conclusions of Kagira and Kanyari (2021), who emphasized the role of improper antibiotic practices in residue contamination.

However, this study also contributes unique insights specific to Zimbabwe's rural context. The lack of veterinary oversight in Rushinga district, coupled with farmers' limited awareness of withdrawal periods, highlights critical gaps in regulatory enforcement and farmer education. These localized findings add depth to the existing body of knowledge and provide actionable data for policymakers.

The results of this study reveal critical insights into the prevalence of antibiotic residues in meat, the drivers of contamination, and their implications for food safety and public health. The finding that 62% of meat samples contained detectable residues, with 38% exceeding safety thresholds, aligns with global research highlighting the widespread misuse of antibiotics in livestock farming (Darwish et al., 2013; Osman et al., 2019). For instance, studies in Kenya and Nigeria reported similar trends of high antibiotic residue levels in poultry and beef from informal markets, where regulation is often minimal (Olatoye, 2020). This study adds to the existing body of evidence by demonstrating that these challenges are equally significant in Zimbabwe's rural contexts, such as Rushinga district.

The high prevalence of tetracyclines in poultry, accounting for 45% of detected residues, is consistent with prior research that identifies tetracyclines as the most commonly misused antibiotics in intensive poultry farming (Abo-Amer et al., 2020). This trend can be attributed to the widespread availability of tetracyclines, their cost-effectiveness, and their perceived efficacy in preventing infections and promoting growth. However, the presence of residues exceeding safety thresholds underscores the failure of farmers to adhere to withdrawal periods; a finding corroborated by Kagira and Kanyari (2021), and highlighted similar practices in small-scale farming systems in sub-Saharan Africa.

The significant positive correlation between antibiotic use frequency and residue levels further emphasizes the role of improper usage practices in driving contamination. This is consistent with van Boeckel et al. (2019), who found that misuse, including non-adherence to withdrawal periods, was a key factor in residue contamination. The strong predictive power of non-adherence to withdrawal periods in this study reinforces the argument that improving farmer awareness and veterinary oversight is critical for mitigating contamination risks.

5.2.1 Generalizations

Based on the dataset of 30 meat samples and a representative survey of 20 livestock farmers, the findings of this study can be generalized to rural livestock farming systems in Zimbabwe, particularly in districts with similar socio-economic and agricultural characteristics to Rushinga. The data indicate that improper antibiotic use is a systemic issue, not limited to isolated cases, and likely reflects broader trends in small-scale livestock farming in sub-Saharan Africa.

The low variability in residue levels within each meat type (as indicated by standard deviations) suggests that the trends observed are consistent and reliable. For instance, poultry consistently showed the highest contamination levels, with minimal variation across sampling sites. This consistency implies that targeted interventions in poultry farming could yield substantial improvements in reducing antibiotic residues. However, generalizations should be cautiously applied to urban or peri-urban settings, where farming practices, market dynamics, and regulatory environments may differ significantly.

While the study identified strong trends and correlations, a few exceptions and anomalies warrant attention. For instance, 30% of goat meat samples exceeded safety thresholds, despite survey data suggesting relatively lower antibiotic usage among goat farmers. This could be attributed to cross-contamination during slaughter and processing, a factor not directly assessed in this study.

Additionally, residue levels in some beef samples from formal retail outlets were higher than expected, despite better regulatory oversight in these markets. This deviation suggests potential weaknesses in meat inspection processes or supply chain management. Such anomalies highlight the complexities of addressing antibiotic residues and underscore the need for further research to identify unaccounted factors contributing to contamination.

5.2.2Causative Factors Discussions

The high prevalence of antibiotic residues in meat can be attributed to several interconnected factors. First, the widespread misuse of antibiotics, including overuse and non-adherence to withdrawal periods, is a primary driver. Farmers in Rushinga district, like their counterparts in other rural areas, often lack access to veterinary services and rely on self-prescription of antibiotics (Kagira&Kanyari, 2021). This practice is exacerbated by limited awareness of the health risks posed by residues, as demonstrated by the survey findings that 70% of farmers used antibiotics without veterinary supervision.

Second, the lack of regulatory oversight, particularly in informal markets, creates an enabling environment for the sale and distribution of contaminated meat. Informal markets are often unregulated, with minimal enforcement of food safety standards. This aligns with findings from South Africa, where informal markets were identified as hotspots for antibiotic residues (Munyaka et al., 2022).

Third, the significant correlation between antibiotic use and residue levels indicates that improper practices, such as failing to observe withdrawal periods, directly contribute to contamination. This is consistent with the One Health Framework, which emphasizes the interconnectedness of human, animal, and environmental health. Improper antibiotic use in livestock not only contaminates meat but also contributes to the broader issue of antibiotic resistance, which poses a global health threat (Lerner & Berg, 2015).

5.2.3 Support for or Refutation of Previous Work

The findings of this study broadly support the conclusions of previous research on antibiotic residues in developing countries. For example:

- The high prevalence of tetracyclines aligns with Darwish et al. (2013), who identified tetracyclines as the most commonly detected residues in sub-Saharan Africa.
- The role of improper practices in driving residue contamination is consistent with van Boeckel et al. (2019), who highlighted similar trends globally.
- The spatial differences observed, with informal markets showing higher contamination levels; support Munyaka et al. (2022), who identified weak regulation as a key factor in informal market contamination.

However, this study refutes the assumption that residue contamination is primarily a result of urban farming practices. By focusing on a rural district, this research demonstrates that small-scale farming systems in rural areas are equally, if not more, prone to residue contamination due to limited access to resources and oversight.

These findings contribute to the growing body of evidence on antibiotic residues and highlight the unique challenges faced by rural farming systems in Zimbabwe and similar contexts.

5.3 Limitations of the Study

While this study provides valuable insights, several limitations must be acknowledged:

1. Sampling Limitations: The study focused on one rural district, which may limit the generalizability of the findings to other regions in Zimbabwe.
2. Self-Reported Data: Survey data on antibiotic use relied on self-reports from farmers, which may be subject to recall bias or underreporting.
3. Temporal Scope: The cross-sectional design provided a snapshot of residue levels but did not account for potential seasonal variations in antibiotic use and residue levels.
4. Methodology limitations: The study's methodology, such as the use of specific testing protocols or sampling procedures, might introduce biases or limitations that impact the accuracy of the findings.
5. Sample size and selection: The study's sample size and selection methodology might impact the accuracy and generalizability of the findings. For instance, a small sample size may not capture the full range of antibiotic residue level in the district.
6. Lack of contextual information: Without sufficient contextual information about farming practices, veterinary care and regulatory frameworks in Rushinga district, it's challenging to interpret the results and develop targeted interventions.

These limitations may affect the validity and applicability of the findings, and future studies should address these gaps by including longitudinal designs and broader geographic coverage.

5.4 Implications for Theory, Research, and Practice

Implications for Theory:

This study validates the application of the One Health Framework and the Theory of Planned Behaviour (TPB) in understanding antibiotic residue contamination. The findings underscore the interconnectedness of human, animal, and environmental health and the role of individual behaviour in antibiotic use.

Implications for Research:

Future research should explore longitudinal trends in antibiotic residues and expand the geographic scope to include urban and peri-urban settings. Comparative studies between formal and informal markets could also provide deeper insights into regulatory gaps.

Implications for Practice:

The findings highlight the urgent need for targeted interventions, including:

- Farmer Education Programs: Training on proper antibiotic use and adherence to withdrawal periods.
- Regulatory Reforms: Strengthening monitoring and enforcement mechanisms, particularly in informal markets.
- Improved Veterinary Services: Expanding access to veterinary support in rural areas to reduce misuse of antibiotics.

5.5 Recommendations for Future Research

1. Conduct longitudinal studies to examine seasonal variations in antibiotic use and residue levels.
2. Investigate the health impacts of long-term exposure to antibiotic residues among consumers in rural Zimbabwe.
3. Expand the scope to include urban and peri-urban markets to provide a comparative analysis of residue levels.

4. Explore the economic and behavioural drivers of antibiotic misuse among small-scale farmers.

5.6 Conclusion

The findings of this study provide critical evidence of the prevalence and drivers of antibiotic residues in meat from Rushinga district, emphasizing the urgent need for improved regulation and farmer education. While consistent with global trends, the study highlights unique challenges in Zimbabwe’s rural context, contributing valuable insights to the growing body of literature on antibiotic residues. Future research and policy interventions should build on these findings to ensure food safety and public health in Zimbabwe.

Chapter 6: Conclusions and Recommendations

6.1 Conclusions

This study investigated the prevalence and drivers of antibiotic residues in meat from Rushinga district of Mashonaland Central Province, Zimbabwe. The findings revealed a significant presence of antibiotic residues in meat, with 62% of samples containing detectable residues and 38% exceeding internationally accepted safety thresholds. Poultry was identified as the most contaminated meat type, with tetracyclines being the predominant antibiotic class detected. A significant positive correlation was found between the frequency of antibiotic use by farmers and the levels of residues detected in meat, with non-adherence to withdrawal periods emerging as a key contributor. These findings underscore the critical role of improper antibiotic use practices in driving contamination, particularly in rural farming systems with limited veterinary oversight.

This study has contributed new knowledge by:

1. Providing localized evidence of antibiotic residue prevalence in rural Zimbabwe, a topic previously underexplored.
2. Highlighting the spatial differences in residue levels between formal and informal markets.
3. Establishing a direct relationship between antibiotic use practices and residue contamination, reinforcing the importance of adherence to withdrawal periods.

The findings emphasize the urgent need for targeted interventions to improve food safety, strengthen regulatory frameworks, and promote responsible antibiotic use in livestock farming.

6.2 Recommendations

Based on the findings of this study, the following recommendations are proposed to address the issue of antibiotic residues in meat:

1. Farmer Education and Awareness Campaigns

Implement training programs to educate farmers on the proper use of antibiotics, including adherence to withdrawal periods and the risks associated with residue contamination.

Develop and disseminate user-friendly educational materials tailored to small-scale farmers in rural areas.

2. Strengthening Veterinary Services

Increase access to veterinary services in rural areas to reduce reliance on self-prescription of antibiotics by farmers.

Provide subsidized veterinary services and medications to encourage proper usage and compliance with recommended practices.

3. Regulatory Reforms and Enforcement

Strengthen regulatory frameworks governing antibiotic use in livestock farming, with a focus on monitoring and enforcement in informal markets.

Introduce mandatory residue testing for meat sold in both formal and informal markets to ensure compliance with safety standards.

Establish traceability systems to monitor the supply chain from farm to market, ensuring accountability for meat safety.

4. Promotion of alternative farming practices.

Promote alternative farming practices, such as organic farming or reduced antibiotic use, to minimize antibiotic residue levels and promote sustainable agriculture.

5. Collaboration and stakeholder engagement

Foster collaboration among stakeholders; including farmers, veterinarians, regulators, and consumers, to raise awareness and promote best practices in antibiotic use and meat production.

6. Support for Informal Markets

Provide support to informal market operators through training on hygiene and food safety standards.

Develop affordable and accessible testing kits for informal markets to detect antibiotic residues.

7. Future Research Directions

Conduct longitudinal studies to assess seasonal variations in antibiotic use and residue levels.

Investigate the health impacts of long-term exposure to antibiotic residues among consumers in rural Zimbabwe.

Explore the economic and behavioural drivers of antibiotic misuse to inform targeted policy interventions.

Expand the scope of research to include other districts and urban areas to develop a national perspective on the issue.

6.3 Way Forward

Addressing the issue of antibiotic residues in meat requires a multi-stakeholder approach involving policymakers, farmers, public health authorities, and market operators. Collaborative efforts should focus on improving awareness, enhancing veterinary oversight, and strengthening regulatory enforcement to ensure food safety and public health in Zimbabwe. By building on the findings of this study, future interventions can effectively reduce antibiotic residues in meat and mitigate the associated risks to consumers.

In conclusion, this study provides critical insights into the challenges of antibiotic residue contamination in rural Zimbabwe, offering a foundation for evidence-based policy development and intervention strategies. Ensuring safe and sustainable livestock farming practices will not only protect public health but also contribute to the long-term viability of Zimbabwe's livestock industry.

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Chapter 8. Appendices

Research Questionnaire: Antibiotic Residues in Meat from Rushinga District**

Respondent Code: ___________

Interview Date: ___________

Respondent Type: Farmer / Trader / Abattoir Worker / Veterinarian (circle one)

Section A: Demographic and Operational Characteristics

(To contextualize farm size and production systems)

1. **Farm/Livestock Details**:

   - Total livestock units owned: Cattle ______ Goats______ Poultry______ Pigs______

   - Primary purpose of rearing: Subsistence ( ) Commercial sale ( ) Both ( )

   - Average time from last antibiotic use to slaughter: __________ days

2. **Meat Supply Chain Role**:

   - How is meat typically sold?

☐ Direct to consumers ☐ Local markets ☐ Abattoirs ☐ Traders

   - Estimated monthly meat sales volume: __________ kg

Section B: Antibiotic Use Practices

(Objective: Identify antibiotics used and application patterns)

3. **Antibiotic Application**:

   - List all antibiotics used in the past 6 months:

Antibiotic Name	Source (Vet/Agro-shop)	Frequency	Reason (Treatment/Prevention/Growth)
_______________	_______________________	__________	____________________________________
_______________	_______________________	__________	____________________________________

4. **Administration Practices**:

- How are antibiotics administered?

☐ Injection ☐ Oral (feed/water) ☐ Topical

- Is dosage measured using:

☐ Veterinary prescription ☐ Product label ☐ Experience

- Withdrawal period awareness: Yes ( ) No ( ) If yes: _________ days

***Section C: Meat Sampling and Residue Analysis Linkage**

(Objective: Correlate antibiotic use with residue levels)

5. **Meat Sample Documentation** *(For paired lab analysis)*:

- Sample ID: __________
- Animal species: __________
- Date of slaughter: __________
- Antibiotics used in last 30 days (if known): __________
- Preslaughter health status: Healthy ( ) Sick ( ) Recently Treated ( )

Section D: Knowledge-Attitude-Practice (KAP) Assessment

(Objective: Understand drivers of residue risks)

6. **Knowledge of Residue Impacts**:

   - Are you aware antibiotic residues in meat can cause:

☐ Antimicrobial resistance (AMR) ☐ Allergic reactions ☐ Unknown

   - How did you learn about antibiotic withdrawal periods?

☐ Vet ☐ Government training ☐ Peer farmers ☐ Never taught

7. **Attitudes Toward Practices**:

   - Rate agreement (1–5) with:

     "Withdrawal periods reduce meat safety risks": 1 2 3 4 5

     "Antibiotics are necessary for healthy animals": 1 2 3 4 5

8. **Constraints to Compliance**:

   - What prevents adherence to withdrawal periods?

☐ Lack of knowledge ☐ Economic pressure ☐ No testing ☐ Other _________

***Section E: Market and Regulatory Environment**

(To contextualize systemic factors)

9. **Regulatory Exposure**:

   - Have you received government guidance on antibiotic use? Yes ( ) No ( )

   - Are meat buyers (abattoirs/traders) inquiring about antibiotic use? Yes ( ) No ( )

10. **Testing Infrastructure**:

    - Are residue tests conducted at:

☐ Farm ☐ Abattoir ☐ Market ☐ Never

    - If tested, frequency: Monthly ( ) Quarterly ( ) Never ( )