International Research Journal of Agriculture, Environment and Animal Sciences

Vol 8, Issue 1, pp 10-16, Nov 21, 2026, © International Research Journal Publishers, ISSN 2710-2742 (online) www.irjp.org

Contrasting Occurrence and Concentration Profiles of Sulfapyridine and Tetracycline in Retail Pork Meat Sold in Nairobi County, Kenya

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Accepted: November 19, 2026

Abstract

Background: Veterinary antibiotic residues in meat are an important food-safety monitoring concern. Detection frequency alone may not adequately describe residue occurrence because compounds detected frequently may occur at comparatively low concentrations, whereas less frequently detected compounds may show substantial concentration variability.

Objective: To compare the occurrence and concentration profiles of Sulfapyridine and Tetracycline residues in pork meat examined in Nairobi County, Kenya.

Methods: This article presents a focused analysis of two compounds selected from the twelve antibiotic residues examined in the study. The study describes a cross-sectional sampling approach, modified QuEChERS-based extraction and liquid chromatography–electrospray ionisation tandem mass spectrometry (LC-ESI-MS/MS). Descriptive findings obtained from the study results were extracted for the two compounds.

Results: The study found 108 pork samples analysed for each compound. Sulfapyridine was detected in 26 samples (24.07%), with a mean concentration of 443.80 µg/kg, standard deviation of 1,238.523 µg/kg and range of 0.50–4,895.90 µg/kg. Seven samples exceeded the 100 µg/kg benchmark applied in the study; the findings compliance was 93.52%. Tetracycline was detected in 99 samples (91.67%), with a mean of 24.28 µg/kg, standard deviation of 33.03 µg/kg and range of .30–220.00 µg/kg. One sample exceeded the 200 µg/kg benchmark applied in the study; the findings compliance was 99.07%.

Conclusion: The compounds showed contrasting profiles. Tetracycline had a higher detection frequency, whereas Sulfapyridine had a substantially higher reported mean, standard deviation and maximum concentration. The study notes that two extreme Sulfapyridine observations influenced its mean. These findings support joint consideration of detection frequency and concentration distribution. Regulatory interpretation of Sulfapyridine requires confirmation of the source and applicability of the comparator used in the study.

Keywords: *Sulfapyridine; Tetracycline; Antibiotic Residues; Pork; Nairobi County; LC-ESI-MS/MS; Concentration Variability; Food Safety*

INTRODUCTION

Antibiotics are used in food-producing animals for the prevention and treatment of bacterial infections and, in some production systems, for other production-related purposes. Their use is

relevant to animal health and livestock productivity; however, residues may remain in edible tissues and enter the human food chain. The presence of veterinary drug residues in food of animal origin is therefore an important food-safety issue (Arsène et al., 2022).

The significance of residue monitoring is not determined solely by whether a compound is detected. Detection frequency, measured concentrations, the distribution of those concentrations and their relationship to applicable residue limits all contribute to interpretation. A compound with a high detection frequency may be present at concentrations below a relevant benchmark in most samples. Conversely, a compound detected less frequently may show substantial variability or unusually high concentrations in a subset of positive samples.

Sulfapyridine and Tetracycline represent two different antimicrobial compounds included in the parent investigation. Sulfapyridine belongs to the sulfonamide group, while Tetracycline belongs to the tetracycline group. The study describes sulfonamides as bacteriostatic antimicrobial agents and tetracyclines as broad-spectrum antibiotics used in veterinary practice. Their different classes and chemical characteristics make compound-specific measurement and interpretation important.

Objective

To compare the occurrence and concentration profiles of Sulfapyridine and Tetracycline residues in pork meat examined in Nairobi County, Kenya.

Materials and Methods

Study design and setting

The study describes a cross-sectional analytical investigation of antibiotic residues in pork meat sold in Nairobi County, Kenya. The study covered pork obtained from retail outlets, butcheries, supermarkets and open-air markets, sampling was undertaken between September and December 2025.

Sampling approach and sample numbers

The study describes stratified random sampling, with Nairobi divided into administrative or commercial zones treated as strata. It refers to ten sampling points from each stratum and states that the sampling design covered 100 retail outlets or sampling sites. 108 samples were analyzed for Sulfapyridine and 108 for Tetracycline.

Sample collection and handling

The study collected data from pork samples from selected retail outlets and markets, placement in labelled containers and transportation to the laboratory in insulated cooler boxes containing ice packs.

Sample preparation and extraction

The study adopted modified QuEChERS-based extraction protocol for simultaneous analysis of twelve antibiotic residues.

Instrumental analysis

The study describes LC-ESI-MS/MS for confirmation and quantification. Reported chromatographic conditions include a C18 reversed-phase column (150 mm × 2.1 mm; 3.5 µm particle size), column temperature of 30 °C, flow rate of 0.3 mL/min and injection volume of 10 µL. The mobile phases are described as aqueous ammonium acetate (10 mM) and acetonitrile, with gradient elution. The mass spectrometer is described as operating in positive and/or negative electrospray ionisation modes according to the target analyte, with multiple reaction monitoring used for quantification.

Quality assurance and method validation

The study involved quality-control measures including reagent blanks, calibration standards, matrix-matched solutions, duplicate analysis and control pork samples. The method validation considered detection limits, recoveries, linearity and precision.

Data extraction and statistical treatment

The article uses the descriptive values reported in the Sulfapyridine and in laboratory analysis. Detection frequency, mean, standard deviation, minimum, maximum, benchmark exceedances and reported compliance are reproduced as stated. Detection frequency is expressed as the number of positive samples divided by the total number of samples analysed, multiplied by 100. The study found compliance as the proportion of all samples not exceeding the benchmark applied to the relevant compound. The percentages are presented as study-reported.

Regulatory comparators

The study applies a comparator of 100 µg/kg for Sulfapyridine and 200 µg/kg for Tetracycline. This study reproduces those values as the benchmarks used in the study.

RESULTS

Occurrence and concentration of Sulfapyridine

Sulfapyridine was detected in 26 of the 108 pork samples analysed, corresponding to a detection frequency of 24.07%. The remaining 82 samples (75.93%) were reported as negative. The mean concentration was 443.80 µg/kg, with a standard deviation of 1,238.523 µg/kg. The reported minimum and maximum concentrations were 0.50 µg/kg and 4,895.90 µg/kg, respectively.

The study found that seven samples exceeded the study-applied benchmark of 100 µg/kg. On this basis, reported compliance was 93.52%. The results further indicate that two unusually high observations had a substantial influence on the mean.

Parameter	Sulfapyridine
Total samples analysed	108
Positive samples	26
Negative samples	82
Detection frequency	24.07%
Mean concentration	443.80 µg/kg
Standard deviation	1,238.523 µg/kg
Minimum concentration	0.50 µg/kg
Maximum concentration	4,895.90 µg/kg
Benchmark applied in thesis	100 µg/kg
Samples above benchmark	7
Compliance	93.52%

Occurrence and concentration of Tetracycline

Tetracycline was detected in 99 of the 108 pork samples analysed, giving a detection frequency of 91.67%. Nine samples (8.33%) were reported as negative. The mean concentration was 24.28 µg/kg, with a standard deviation of 33.03 µg/kg. Concentrations ranged from 5.30 µg/kg to 220.00 µg/kg. The study applied a benchmark of 200 µg/kg and reported one sample above this value. The corresponding reported compliance was 99.07%.

Parameter	Tetracycline
Total samples analysed	108
Positive samples	99
Negative samples	9
Detection frequency	91.67%
Mean concentration	24.28 µg/kg
Standard deviation	33.03 µg/kg
Minimum concentration	5.30 µg/kg
Maximum concentration	220.00 µg/kg
Benchmark applied in thesis	200 µg/kg
Samples above benchmark	1

Compliance	99.07%

Comparative residue profile

Tetracycline had a higher detection frequency than Sulfapyridine (91.67% versus 24.07%). In contrast, the reported mean concentration for Sulfapyridine (443.80 µg/kg) was higher than that for Tetracycline (24.28 µg/kg). Sulfapyridine also had a much larger reported standard deviation and maximum concentration.

Indicator	Sulfapyridine	Tetracycline
Samples analysed	108	108
Positive samples	26	99
Detection frequency	24.07%	91.67%
Mean (µg/kg)	443.80	24.28
Standard deviation (µg/kg)	1,238.523	33.03
Minimum (µg/kg)	0.50	5.30
Maximum (µg/kg)	4,895.90	220.00
Study-applied benchmark (µg/kg)	100	200
Samples above benchmark	7	1
Reported compliance	93.52%	99.07%

The comparison demonstrates distinct occurrence and concentration patterns between the two compounds within the sampled pork.

Discussion

Contrasting detection frequencies

The principal descriptive finding is the difference in detection frequency between the two compounds. Tetracycline was detected in 91.67% of samples, compared with 24.07% for Sulfapyridine. Within the limits of the sampling design and analytical information reported in the study, measurable Tetracycline residues were more widespread in the sampled pork than measurable Sulfapyridine residues. The Kenyan study by Bor et al. (2023), as cited and summarised in the study, provides context for the relevance of pork residue surveillance. Their use of a micro-inhibition screening method differs from the compound-specific LC-MS/MS approach described in the study. The studies are contextually relevant but their prevalence estimates should not be treated as directly interchangeable.

Sulfapyridine concentration variability

The Sulfapyridine summary is characterised by a mean of 443.80 µg/kg and a standard deviation of 1,238.523 µg/kg, with a maximum of 4,895.90 µg/kg. The standard deviation exceeds the mean, and the maximum is substantially higher than the mean.

Tetracycline occurrence and concentration

Tetracycline was detected in nearly all analysed samples, but its reported mean concentration was 24.28 µg/kg. The reported maximum was 220.00 µg/kg, and one sample exceeded the 200 µg/kg benchmark applied in the study. Thus, high detection frequency coexisted with a substantially lower reported mean concentration than that of Sulfapyridine.

The study describes tetracyclines as broad-spectrum antimicrobial agents used in veterinary medicine and identifies their relevance to food-producing animals. The findings establish that Tetracycline residues were frequently detected in the sampled pork.

Interpretation of benchmark exceedances

The study found seven Sulfapyridine samples above 100 µg/kg and one Tetracycline sample above 200 µg/kg. These findings correspond to compliance percentages of 93.52% and 99.07%, respectively.

Implications for residue surveillance

The two profiles indicate that surveillance should consider detection frequency together with the magnitude and variability of measured concentrations. Tetracycline's high detection frequency makes it relevant to routine monitoring. These findings suggest complementary surveillance priorities: continued routine monitoring of Tetracycline and focused analytical verification of the high Sulfapyridine observations.

Strengths and limitations

A strength of the focused analysis is that the two compounds were examined within the same parent investigation and pork-sampling context. The study describes a multi-residue LC-ESI-MS/MS approach and reports compound-specific detection and concentration summaries, providing a basis for descriptive comparison. The study was limited to pork samples collected in Nairobi County during the stated sampling period and to the twelve antibiotic residues included in its analytical scope. The findings should therefore be interpreted within that geographical, temporal and analytical scope.

Conclusion

The study established that Sulfapyridine and Tetracycline residues were present in pork meat sold in Nairobi County, demonstrating that veterinary antibiotic residues remain an important food-safety concern within the pork supply chain. However, the two compounds exhibited distinctly different occurrence and concentration patterns. Tetracycline was characterised by widespread detection across the sampled pork, suggesting that its presence was not confined to isolated retail samples. Sulfapyridine, although detected less frequently, exhibited considerably greater concentration variability, including exceptionally elevated concentrations in some samples. These findings demonstrate that the occurrence of antibiotic residues cannot be adequately understood through detection frequency alone, but requires consideration of the concentrations and distribution patterns of individual compounds.

The concentration profiles further established an important distinction between the two antibiotics. Tetracycline residues were generally characterised by comparatively lower concentrations despite their widespread occurrence, whereas Sulfapyridine presented a more concerning concentration profile because of the elevated levels recorded in some samples. The occurrence of Sulfapyridine at concentrations exceeding the comparison threshold applied in the study indicates that isolated instances of substantial residue contamination may occur even when the overall detection frequency is relatively low. Conversely, the frequent detection of Tetracycline demonstrates that a compound may be widespread in the food supply without necessarily exhibiting similarly elevated concentrations. The findings therefore establish the importance of evaluating antibiotic residues individually rather than relying on generalised assessments of antimicrobial contamination in pork.

Overall, the study concludes that Sulfapyridine and Tetracycline present different but complementary food-safety considerations in pork consumed in Nairobi County. Sulfapyridine warrants particular attention because of its elevated concentration profile and its contribution to estimated dietary exposure, while Tetracycline deserves continued monitoring because of its widespread occurrence in the sampled pork. The findings demonstrate the need for compound-specific residue surveillance, effective enforcement of applicable veterinary drug residue standards and responsible antimicrobial use throughout the pork production and distribution chain. They also provide an empirical basis for strengthening food-safety management through collaboration among veterinary practitioners, livestock producers, meat inspectors, regulatory agencies and public-health authorities. Ultimately, controlling antibiotic residues in pork requires an approach that addresses both the widespread occurrence of antimicrobial compounds and the potential significance of elevated concentrations in individual food sample.

Recommendations

Routine residue surveillance in retail pork should include both Sulfapyridine and Tetracycline and should assess detection frequency alongside measured concentrations. The detection of Tetracycline in 91.67% of the samples indicates that monitoring should not be restricted to occasional or suspicion-based testing. Regular sampling across butcheries, supermarkets and open-air markets would provide a more consistent picture of its occurrence in pork available to consumers. Surveillance reports should present the number of samples tested, positive samples, detection frequency, concentration range, mean and standard deviation so that the extent and magnitude of residue occurrence can be interpreted together.

Food-safety and veterinary regulatory authorities should give particular attention to samples containing Sulfapyridine concentrations above the 100 µg/kg benchmark and Tetracycline concentrations above the 200 µg/kg benchmark applied in this study. The seven Sulfapyridine and one Tetracycline exceedances demonstrate that benchmark exceedances occurred for both compounds, even though the findings indicated compliance percentages were high. Regulatory monitoring should therefore incorporate appropriate follow-up of non-compliant consignments and retail sources, in accordance with applicable national procedures. Clear communication of residue requirements to meat inspectors, retailers, suppliers and relevant veterinary personnel would support consistent implementation of food-safety controls.

Veterinary practitioners, pig producers and other actors involved in the pork supply chain should strengthen responsible antimicrobial-use practices. The widespread detection of Tetracycline and the high concentrations recorded for some Sulfapyridine-positive samples make it important that antibiotics are used under appropriate veterinary direction and that withdrawal periods are observed before animals enter the food chain. Producers and suppliers should maintain treatment records that identify the medicine used, date of administration, animal or group treated and withdrawal period. Such practices can support traceability and help prevent pork containing avoidable antibiotic residues from reaching retail markets.

Retailers, slaughter facilities and pork suppliers should strengthen procurement and traceability arrangements so that meat entering the market can be linked to its source. Suppliers should obtain pork from production systems that maintain veterinary treatment records and follow established withdrawal requirements. Retail operators should cooperate with competent authorities during residue surveillance and should respond appropriately when a sample is found to exceed an applicable residue limit. These measures are particularly relevant given the contrasting findings: Tetracycline requires attention because it was detected in most samples, while Sulfapyridine requires attention because of its wide concentration range and the high values recorded in a subset of samples.

Public health and food-safety agencies should use the findings to support targeted consumer and stakeholder education on veterinary drug residues and safe meat production. Communication should explain that frequent detection, concentration magnitude and exceedance of a residue benchmark are different measures and should not be conflated. Education for producers and suppliers should emphasise veterinary oversight, accurate treatment documentation and observance of withdrawal periods, while engagement with retailers should reinforce sourcing from traceable suppliers. These actions would translate the study's comparative findings into practical measures aimed at reducing the occurrence of residues in pork offered for sale in Nairobi County.

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