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GLOBAL RESEARCH TRENDS IN FLORFENICOL: A FOUR-DECADE BIBLIOMETRIC ANALYSIS OF SCIENTIFIC EVOLUTION FROM VETERINARY THERAPEUTICS TO ENVIRONMENTAL AND RESISTANCE CONCERNS

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Abstract

Florfenicol, a broad-spectrum antibiotic extensively used in veterinary medicine, has gained significant attention in recent research because of growing concerns about antimicrobial resistance and its environmental impacts, particularly within the context of the One Health approach. A comprehensive bibliometric analysis of 972 florfenicol publications indexed in Scopus (1986-2025) was conducted using Bibliometrix R package and VOSviewer. Multiple indicators were assessed including annual production trends, journal distribution, author productivity, institutional affiliations, international collaborations, citation patterns, and thematic evolution through keyword analysis. Florfenicol research demonstrated remarkable growth with a 10.55% annual increase, evolving through four distinct phases from minimal activity (1986-1999) to exponential expansion (2018-2025). China dominated with 401 corresponding author publications (41.3%), followed by the USA (84 articles, 8.6%). Strong international collaboration was observed (17.6% multi-country publications), particularly between China and the USA (32 joint studies). Thematic evolution shifted from basic pharmacokinetics and residue studies to contemporary

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focus on antimicrobial resistance genes, impact on the environment, and advanced analytical methods. Highly cited studies emphasized resistance mechanisms and environmental dissemination. Florfenicol research has transformed from a niche veterinary topic into a multidisciplinary domain addressing global antimicrobial resistance challenges. The field demonstrates strong international collaboration but reveals geographic disparities requiring attention. Future research should prioritize prevention strategies over detection methods while establishing networks linking high-output countries with underrepresented regions for comprehensive global resistance surveillance.

Key words: Bibliometric analysis, antibiotics, resistance to antibiotics, veterinary medicine, florfenicol, research data

GLOBALNI TRENDOWI U ISPITIVANJU FLORFENIKOLA: BIBLIOMETRIJSKA ANALIZA NAUČNE EVOLUCIJE DUGE 4 DEцениJE- OD TERAPIJE U VETERINI DO ANTIMIKROBNE REZISTENCIJE

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Kratak sadržaj

Florfenikol, antibiotik širokog spektra koji se intenzivno koristi u veterinarskoj medicini, privukao je značajnu pažnju u novijim istraživanjima zbog sve veće zabrinutosti u vezi sa antimikrobnom rezistencijom i njegovim uticajem na životnu sredinu, naročito u kontekstu pristupa "Jedno zdravlje". Sprovedena je sveobuhvatna bibliometrijska analiza 972 publikacije o florfenikolu indeksirane u bazi Scopus (1986–2025), putem Bibliometrix-a u programu R i softvera VOSviewer. Procenjavani su brojni pokazatelji, uključujući godišnje trendove publikovanja, distribuciju časopisa, produk-

tivnost autora, institucionalne afilijacije, međunarodne kolaboracije, obrasce citiranja i tematsku evoluciju putem analize ključnih reči. Istraživanja o florfenikolu pokazala su izuzetan rast sa prosečnim godišnjim povećanjem od 10,55%. Rast je tekao kroz četiri jasno definisane faze - od minimalne aktivnosti (1986–1999) do eksponencijalne ekspanzije (2018–2025). Kina je dominirala sa 401 publikacijom kao i autorima iz te zemlje (41,3%), a sledile su Sjedinjene Američke Države sa 84 rada (8,6%). Uočen je visok nivo međunarodne saradnje (17,6% publikacija sa više zemalja), naročito između Kine i SAD (32 zajednička istraživanja). U smislu tematskih promena, fokus se pomerio sa osnovnih studija farmakokinetike i ostataka leka ka genima antimikrobne rezistencije, uticaja na životnu sredinu i napredne analitičke metode. Najcitiranije studije isticale su mehanizme rezistencije i širenje u životnoj sredini. Istraživanja o florfenikolu promenila su kurs od usko specijalizovanih veterinarskih tema u multidisciplinarnu oblast koja se bavi globalnim izazovima antimikrobne rezistencije. U ovoj oblasti je prisutna izržena međunarodna saradnja, ali i geografske neujednačenosti kojima se treba baviti u budućnosti. Prioritet budućih istraživanja trebalo bi da budu strategije prevencije u odnosu na metode detekcije, uz uspostavljanje mreža koje povezuju zemlje sa visokim istraživačkim učinkom i nedovoljno zastupljene regione radi sveobuhvatnog globalnog praćenja antimikrobne rezistencije.

Ključne reči: Bibliometrička analiza, antibiotici, atpornost na antibiotike, veterinarska medicina, istraživački podaci

INTRODUCTION

Florfenicol is a broad-spectrum, synthetic antibiotic belonging to the amphenicol class, structurally related to chloramphenicol and thiamphenicol (Lunestad and Samuelsen, 2008, Trif et al., 2023a). Since its development in the late 20th century, it has been widely used in veterinary medicine (Trif et al., 2023a), particularly in livestock and aquaculture (Lunestad and Samuelsen, 2008), due to its effectiveness against Gram-positive and Gram-negative bacteria (Trif et al., 2023a), favorable pharmacokinetic properties (Huynh et al., 2025), and comparatively lower risk of resistance compared with other antimicrobials in the same class (Trif et al., 2023b). Its approval for use in food-producing animals was driven largely by the need for an alternative to chloramphenicol (Adesoji and Call, 2020, Dowling, 2013), which was banned in many

countries owing to safety concerns in humans (Hanekamp and Bast, 2015), particularly for the risk of aplastic anemia in humans (Dowling, 2013). Florfenicol's relative safety profile, coupled with its strong antibacterial activity, made it an attractive therapeutic option in managing respiratory and enteric infections in cattle, swine, poultry, and fish (Trif et al., 2023a).

Despite its benefits, the use of florfenicol has also prompted significant scientific and public health concerns. The emergence of antimicrobial resistance (AMR) linked to florfenicol exposure has been increasingly reported in both clinical and environmental isolates, particularly in aquaculture systems where the drug is extensively applied (Miranda et al., 2013, Nüesch-Inderbinen et al., 2023). Genes such as *floR*, conferring florfenicol resistance, have been detected in diverse bacterial species and mobile genetic elements, heightening the risk of horizontal transfer and global dissemination (Lu et al., 2018). This has placed florfenicol at the intersection of veterinary practice, food safety, environmental microbiology, and the One Health framework. Consequently, the scientific literature on florfenicol has expanded to cover diverse themes, including its pharmacology (Selimov et al., 2023), resistance mechanisms (Müller et al., 2022), clinical applications (Watteyn et al., 2013), toxicology (Wang et al., 2021), environmental studies (Zhao et al., 2024).

Bibliometric analysis is a quantitative study of research publications in certain fields using mathematical and statistical methods. It provides valuable information about the research trends, evolving topics and quantitative analysis of citations, authors, institutes, countries contributions and thematic maps (Darvish, 2020, van Eck and Waltman, 2010, Kandeel and Mahmoud, 2025, Alsaleem et al., 2025). Bibliometric analysis is a valuable tool for mapping and evaluating scientific knowledge. Bibliometric analysis of florfenicol research can offer valuable insights into research growth, global contributions, and thematic shifts related to its clinical use, resistance, and regulatory challenges. Although bibliometric analyses have explored antibiotics, antimicrobial resistance (Sun et al., 2022), and veterinary pharmaceuticals in general (Arshad et al., 2020), a comprehensive assessment dedicated exclusively to florfenicol has not yet been conducted. Considering florfenicol's pivotal role in animal health and its significance within ongoing antibiotic stewardship discussions, undertaking such an assessment is both timely and recommended.

This study therefore conducts a bibliometric analysis of global florfenicol literature using data from Scopus database. The objectives are the following: (1) mapping research trends; (2) identifying leading authors, institutions, journals, and countries; and (3) exploring thematic evolution and emerging hot-spots, particularly in relation to use, resistance, and One Health implications.

Through this approach, we aim to clarify how florfenicol research has developed, where it stands today, and potential directions for future investigation.

MATERIAL AND METHODS

Study Design

This study employed a bibliometric approach to deliver a comprehensive overview of global research on florfenicol.

Data Source and Search Strategy

The data were retrieved from the Scopus database, selected for its broad coverage of peer-reviewed journals across scientific disciplines and its compatibility with bibliometric tools. A topic search was conducted using the keyword "florfenicol". The search period extended from inception through August 2025, covering nearly four decades of research activity. To ensure data quality and relevance, only original research articles were included, while reviews, conference proceedings, editorials, and letters were excluded. Only articles published in English were included to minimize the risk of misinterpretation from other languages. The search query in Scopus included the following: (TITLE (Florfenicol) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar"))) AND (EXCLUDE (PREFNAMEAUID, "undefined"))).

Data Extraction and Processing

All bibliographic records were exported from Scopus in RIS and CSV formats with complete metadata fields, including author names, titles, abstracts, keywords, affiliations, journals, references, and citation counts. The dataset was then imported into the Bibliometrix R package (version 4.2.0) via the Biblioshiny interface for cleaning and processing (Darvish, 2020).

Bibliometric Indicators

Multiple bibliometric indicators were assessed to characterize the research landscape. Annual scientific production was examined to track trends in publication output. Journal-level analysis was conducted to identify the most influential publication sources. Author productivity and impact were evaluated through total publication counts and fractionalized authorship contributions.

Institutional and country-level productivity was analyzed based on corresponding author affiliations, distinguishing between single-country publications (SCP) and multi-country publications (MCP). Citation analysis identified the most influential studies, considering both total citations and normalized citation counts to account for differences in publication year.

Analytical Tools and Visualization

Bibliometric and network analyses were performed using Bibliometrix (Darvish, 2020) and VOSviewer (version 1.6.20) (van Eck and Waltman, 2010). These tools enabled the construction of co-authorship networks, international collaboration maps, and keyword co-occurrence clusters. Keyword analysis was applied to trace the chronological evolution of research focus and detect emerging topics. Visualization of results was carried out using Bibliometrix, VOSviewer, and Microsoft Excel, generating figures such as annual publication trends, institutional and journal distributions, international collaboration networks, and keyword evolution maps.

RESULTS

The bibliometric dataset comprised 972 publications on florfenicol indexed in Scopus between 1986 and 2025, originating from 367 different sources. Overall, scientific output demonstrated an annual growth rate of 10.55%, with documents averaging 8.87 years of age and 23.26 citations per article. The dataset included 31,854 references, 1,993 author keywords, and 6,748 Keywords Plus, reflecting broad thematic coverage. A total of 3,356 authors contributed, with a strong collaborative pattern averaging 6.14 co-authors per paper and an international co-authorship rate of 17.6%.

Annual Scientific Production and Trends

The bibliometric analysis revealed a remarkable evolution in florfenicol research over four decades, with scientific production growing from a single publication in 1986 to 94 articles in 2024. The distribution demonstrates four distinct phases of research development. The emergence phase (1986-1999) showed minimal activity. The steady growth phase (2000-2012) witnessed consistent expansion with 216 articles, marking the beginning of sustained research interest. The acceleration phase (2013-2017) produced 174 articles in just five years, indicating growing recognition of florfenicol's importance. The exponential expansion phase (2018-2025) generated 539 articles, representing

more than half of total publications in merely eight years. A marked growth spurt occurred after 2018, with annual publications consistently surpassing 40 articles. The year 2024 marked the peak with 94 publications, while 2025 already shows 50 articles by mid-year (Figure 1).

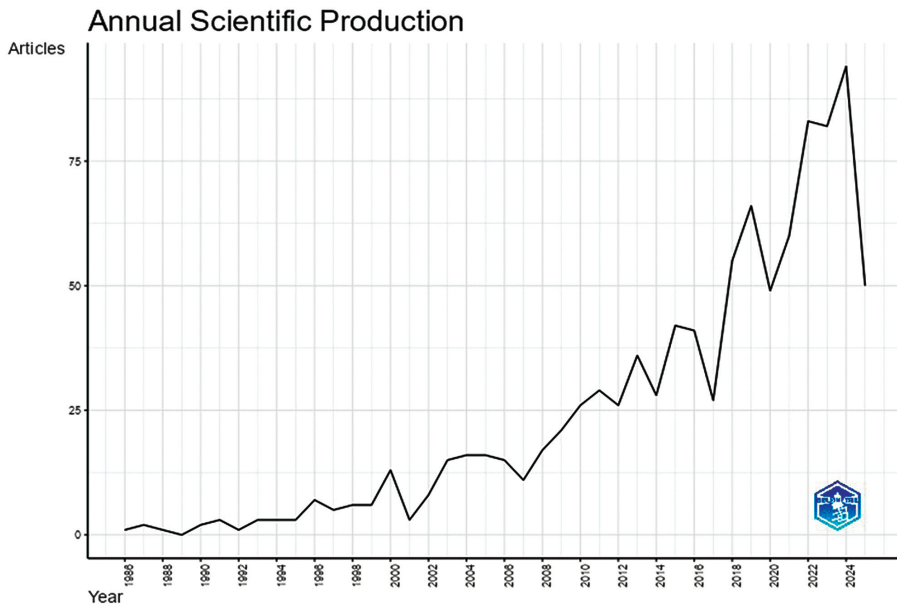


Figure 1. Annual scientific production of florfenicol research (1986–2025).

Journal Distribution and Publication Venues

Florfenicol research exhibits notable interdisciplinary scope, with the *Journal of Veterinary Pharmacology and Therapeutics* leading the field with 61 publications (6.3% of total output). Aquaculture journals contributed significantly with 49 articles (Aquaculture: 38, Aquaculture Research: 11), reflecting the compound's extensive use in fish farming. Environmental science publications appeared in *Ecotoxicology and Environmental Safety* (22), *Science of the Total Environment* (14), and *Environmental Science and Pollution Research* (10). Analytical chemistry studies were published in the *Journal of Chromatography B* (13), *Journal of AOAC International* (14), and *Chemical Engineering Journal* (14). Veterinary medicine research featured in the *American Journal of Veterinary Research* (11) and *Frontiers in Veterinary Science* (10). Microbiology and resistance studies were represented by *Antimicrobial Agents and Chemotherapy* (15) and *Frontiers in Microbiology* (11) (Table 1).

Table 1. Most relevant journals publishing florfenicol research

Sources	Articles
JOURNAL OF VETERINARY PHARMACOLOGY AND THERAPEUTICS	61
AQUACULTURE	38
ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	22
JOURNAL OF FISH DISEASES	19
ANTIMICROBIAL AGENTS AND CHEMOTHERAPY	15
JOURNAL OF AQUATIC ANIMAL HEALTH	15
ANTIBIOTICS	14
CHEMICAL ENGINEERING JOURNAL	14
JOURNAL OF AOAC INTERNATIONAL	14
SCIENCE OF THE TOTAL ENVIRONMENT	14
JOURNAL OF CHROMATOGRAPHY B: ANALYTICAL TECHNOLOGIES IN THE BIO-MEDICAL AND LIFE SCIENCES	13
POULTRY SCIENCE	12
AMERICAN JOURNAL OF VETERINARY RESEARCH	11
AQUACULTURE RESEARCH	11
FRONTIERS IN MICROBIOLOGY	11

Author Productivity and Collaboration Patterns

Author analysis reveals concentrated expertise among leading researchers. Li J and Liu Y emerged as the most productive authors with 33 articles each, though their fractionalized contributions differ significantly (5.54 and 4.16 respectively), indicating varying collaboration intensities. Wang X contributed 31 articles with 4.19 fractionalized publications, while Li X and Zhang Y each published 30 articles. Schwarz S stands out with the highest fractionalized contribution (6.43) from 23 total articles, demonstrating lower number of coauthors (Table 2).

Table 2. Top author productivity and impact analysis in florfenicol research

Authors	Articles	Articles Fractionalized
LI J	33	5.536544012
LIU Y	33	4.157669128
WANG X	31	4.189357864
LI X	30	4.023445019
ZHANG Y	30	3.898004202
WANG Y	26	3.399473158
LI Y	23	3.361446886
SCHWARZ S	23	6.431385281
ZHANG L	20	2.832178932

Institutional Landscape and Research Centers

Institutional analysis indicates pronounced geographical clustering, with Chinese universities leading the output of florfenicol research. China Agricultural University leads with 146 articles, followed by South China Agricultural University with 126 articles. Yangzhou University contributed 89 articles, and Wenzhou Medical University produced 84, reflecting a medical research perspective. In contrast, China Agricultural University (146), South China Agricultural University (126), Huazhong Agricultural University (78), Sichuan Agricultural University (70), Hebei Agricultural University (66), and Nanjing Agricultural University (63) highlight the compound's focus on agricultural and veterinary applications (Table 3).

Table 3. Top institutional affiliations and research centers in florfenicol research

Affiliation	Articles
CHINA AGRICULTURAL UNIVERSITY	146
SOUTH CHINA AGRICULTURAL UNIVERSITY	126
YANGZHOU UNIVERSITY	89
WENZHOU MEDICAL UNIVERSITY	84
HUAZHONG AGRICULTURAL UNIVERSITY	78
DONGGUAN UNIVERSITY OF TECHNOLOGY	73

Affiliation	Articles
SICHUAN AGRICULTURAL UNIVERSITY	70
HEBEI AGRICULTURAL UNIVERSITY	66
NATIONAL CHUNG HSING UNIVERSITY	66
GHENT UNIVERSITY	64
NANJING AGRICULTURAL UNIVERSITY	63
JILIN UNIVERSITY	59
UNIVERSIDAD DE CONCEPCIÓN	58

Three field plots also indicate that China clearly leads the field, with top institutions such as China Agricultural University, Wenzhou Medical University, and Sichuan University of China contributing most of publications. Their work is strongly tied to topics including florfenicol, pharmacokinetics, antimicrobial resistance, and oxidative stress (Figure 2A).

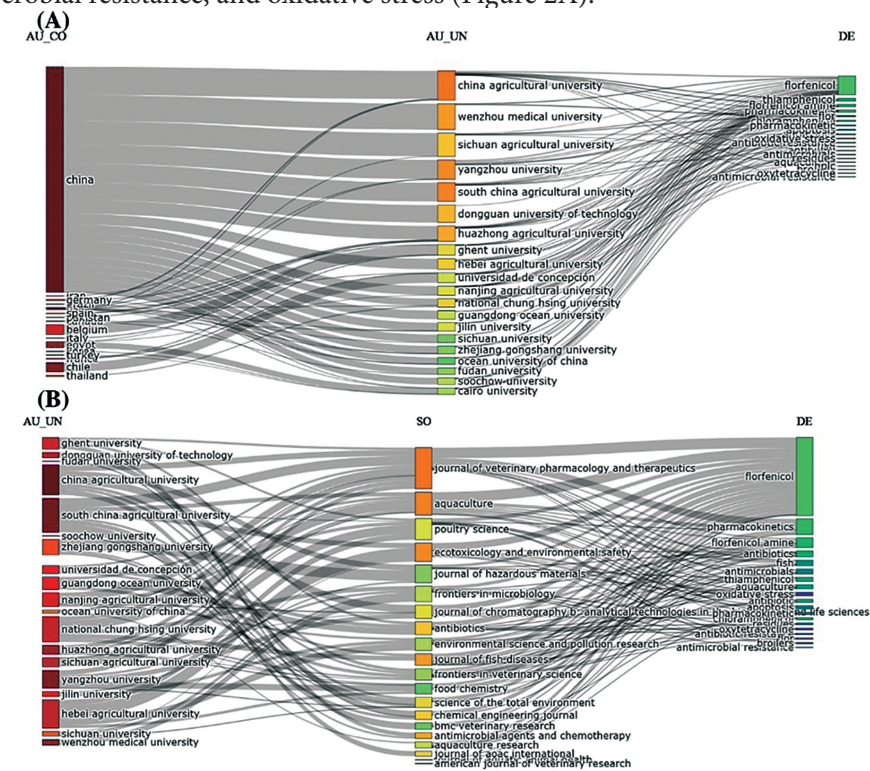


Figure 2. Geographic, Institutional, and Journal Distribution in Florfenicol Research.

Institutional output aligns closely with specific journals - particularly the Journal of Veterinary Pharmacology and Therapeutics, Aquaculture, Poultry Science and Ecotoxicology and Environmental Safety - reflecting a strong focus on veterinary and aquatic applications. The most frequent keywords, including florfenicol, pharmacokinetics, florfenicol amine, antibiotics, and tissue distribution, highlight the thematic emphasis on drug metabolism, resistance, and environmental safety (Figure 2B).

Global Research Distribution, Country Contributions, and Collaboration Map

Florfenicol research demonstrates a strong geographical concentration, with China leading as the corresponding author country, contributing 401 articles (41.3% of global output) (Figure 3). These findings confirm China's clear leadership in florfenicol research, with 345 single-country publications (86.0%) and 56 multi-country collaborations (14.0%). The United States ranks second, contributing 84 articles (8.6%) as corresponding author and demonstrating a greater inclination toward international collaboration, with 19.0% of its publications involving multiple countries. Chile follows in third with 32 articles (3.3%), closely followed by Egypt (29 articles, 2.9%) and Brazil (26 articles, 2.7%).

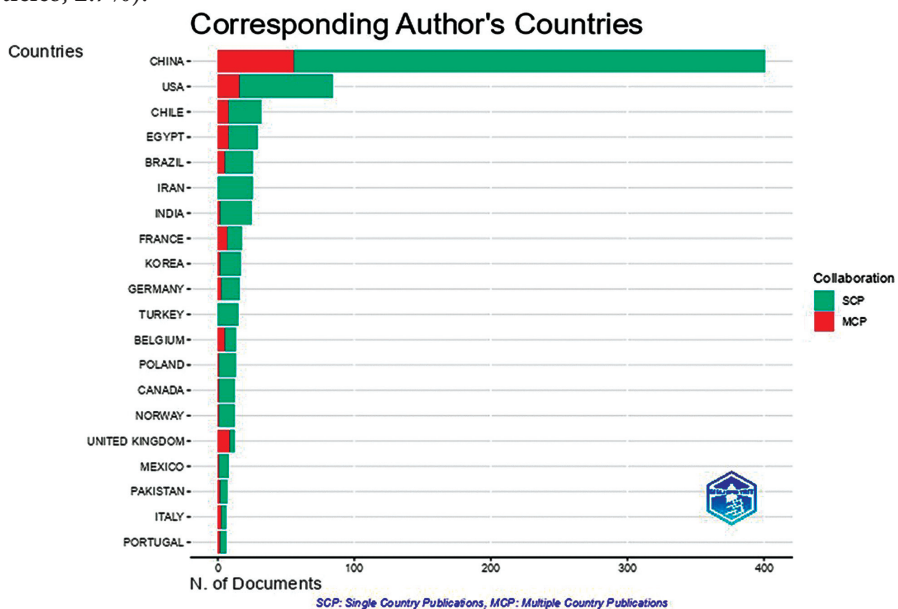


Figure 3. Corresponding author countries for florfenicol research (1986–2025).

The global research landscape on florfenicol demonstrates extensive international collaboration, with the United States and China emerging as the central hubs (Figure 4 and Table 4). China shows the strongest partnerships with the USA (32 studies), Thailand (9), Pakistan and Egypt (5 each), and Germany (4). Similarly, the USA maintains strong collaborations with Canada (8), the United Kingdom (10), and Norway (5).

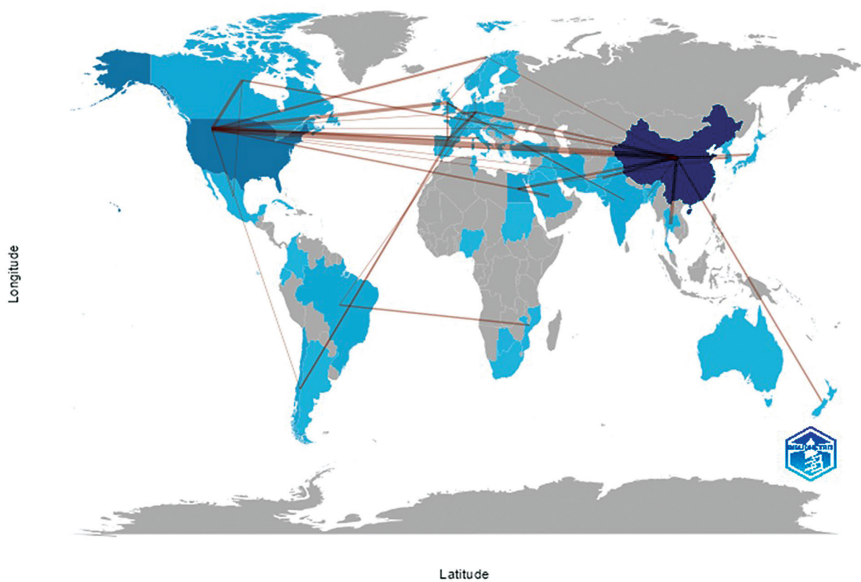


Figure 4. Country Scientific Production and Global Collaborations in Florfenicol Research.

Table 4. The top scores in international collaboration in florfenicol research

From	To	Articles
CHINA	USA	32
USA	UNITED KINGDOM	10
CHINA	THAILAND	9
USA	CANADA	8
EGYPT	SAUDI ARABIA	6
CHINA	EGYPT	5

From	To	Articles
CHINA	PAKISTAN	5
FRANCE	GERMANY	5
USA	NORWAY	5
CHINA	GERMANY	4
BELGIUM	GERMANY	3
BRAZIL	MOZAMBIQUE	3
CHILE	SPAIN	3
CHINA	CANADA	3
CHINA	JAPAN	3
CHINA	KOREA	3
CHINA	NEW ZEALAND	3
UNITED KINGDOM	BELGIUM	3
UNITED KINGDOM	FRANCE	3
USA	EGYPT	3

Most global cited studies

The distribution of florfenicol research by authors' nationality highlights a clear dominance of China, with 2,966 citations, surpassing other countries by far. The United States follows with 697 citations, while Chile (217), Egypt (170), and India (170) represent notable contributors from South America, Africa, and Asia. Brazil (152), South Korea (115), and Iran (108) also demonstrate strong regional outputs. European influence is reflected through the UK (98), Belgium (93), France (89), Germany (78), and Poland (77), underscoring diverse international participation (Figure 4).

The most highly cited studies on florfenicol span microbiology, antimicrobial resistance, and environmental impacts (Table 5).

Table 5. Most global cited studies in Florfenicol Research

Paper	DOI	Total Cita-tions	TC per Year	Normal-ized TC
KEHREN- BERG C, 2006, ANTIMICRO- BIAL AGENTS CHEMOTHER	10.1128/ AAC.50.4.1156- 1163.2006	368	18.4	6.773006135
SCHWARZ S, 2000, AN- TIMICRO- BIAL AGENTS CHEMOTHER	10.1128/ AAC.44.9.2530- 2533.2000	302	11.61538462	3.508489723
CAO Z, 2017, ENVIRON SCI TECHNOL	10.1021/acs. est.7b02480	290	32.22222222	7.925101215
KEHRENBERG C, 2005, MOL MICROBIOL	10.1111/j.1365- 2958.2005.04754.x	288	13.71428571	4.992416035
JIANG W-L, 2018, EN- VIRON SCI TECHNOL	10.1021/acs. est.8b01894	240	30	8.499678042
GUILHER- MINO L, 2018, SCI TOTAL ENVIRON	10.1016/j.scito- tenv.2017.12.020	217	27.125	7.685125563
WHITE DG, 2000, J CLIN MICROBIOL	10.1128/ jcm.38.12.4593- 4598.2000	182	7	2.114387846
MITCHELL SM, 2013, BI- ORESOUR TECHNOL	10.1016/j.bi- ortech.2013.09.048	173	13.30769231	6.12992126

Kehrenberg et al. 2006 (368 citations) investigated the genetic basis of florfenicol resistance in bacterial isolates (Kehrenberg and Schwarz, 2006). Schwarz et al. 2000 (302 citations) examined resistance mechanisms (Schwarz et al., 2000). Cao et al. 2017 (290 citations) explored the environmental dissemination of florfenicol residues and associated resistance genes (Cao et al., 2017). Kehrenberg et al. 2005 (288 citations) focused on molecular pathways underlying resistance development (Kehrenberg et al., 2005). Jiang et al. 2018 (240 citations) analyzed wastewater treatment as a potential source of resistance spread (Jiang et al., 2018). White et al. 2000 (182 citations) reported resistant bacteria in clinical samples (White et al., 2000). Mitchell et al. 2013 (173 citations) evaluated treatment technologies to decrease environmental contamination (Mitchell et al., 2013).

Research Evolution and Emerging Trends

Trend analysis reveals significant thematic evolution from basic compound characterization to complex multidisciplinary investigations (Figure 5). Early research (2006-2012) focused on fundamental aspects: floR gene studies (median year: 2007), residue depletion (2012), and analytical methods like ELISA (2014). The intermediate period (2013-2019) expanded to therapeutic applications with pharmacokinetic studies (median: 2018), species-specific investigations in rainbow trout (2015) and tilapia (2016), and resistance mechanisms. Contemporary research (2020-2025) emphasizes critical concerns: antibiotic resistance genes (median: 2023), environmental applications including adsorption studies (2024), and advanced materials like molecularly imprinted polymers (2023). Compound-specific terms show sustained growth: florfenicol (533 total occurrences, median: 2019), florfenicol amine (56 occurrences), and thiamphenicol (38 occurrences). Methodological evolution progresses from basic HPLC (median: 2016) to sophisticated LC-MS/MS techniques (2017). Recent emergence of terms like "inflammation" (2024), "egg" (2024), and "pig" (2023) indicates expanding therapeutic applications and food safety concerns.

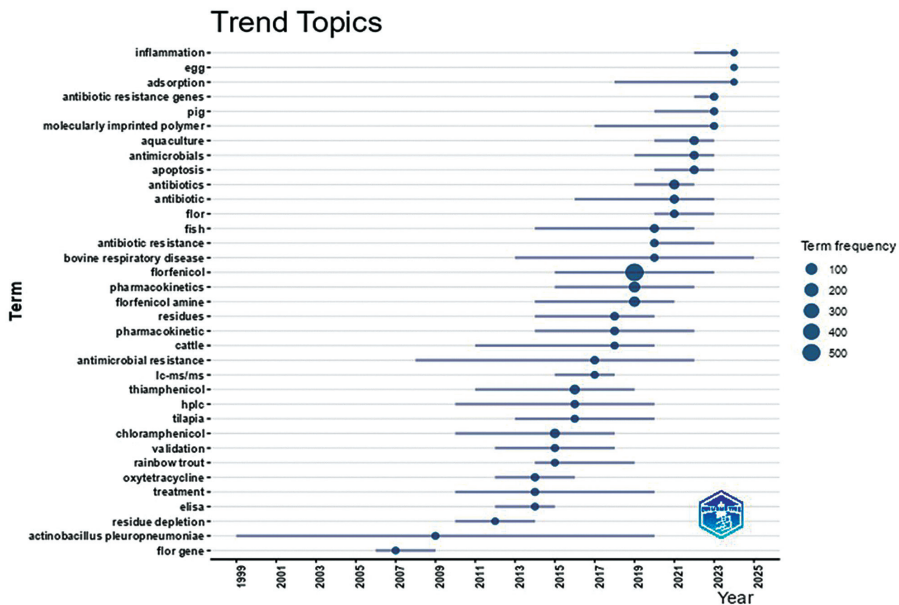


Figure 5. Trend Topics in Florfenicol Research.

Centrality analysis

Centrality analysis provides deeper insight into how research topics on florfenicol are interconnected within the scientific network. The "florfenicol" cluster stands out with the highest betweenness centrality (7632.9) and PageRank score (0.198), establishing it as the central hub connecting multiple thematic domains. Within this cluster, co-occurring terms such as *pharmacokinetics*, *florfenicol amine*, *thiamphenicol*, and *chloramphenicol* also show high centrality, reflecting their strong influence in bridging experimental, clinical, and residue-focused studies. The "antibiotics" cluster also exhibits substantial centrality, with *antibiotics* (2448.6) and *aquaculture* (1930.2) acting as major connectors, particularly in relation to fish and livestock health. Meanwhile, the "antimicrobial resistance" cluster contributes key bridging nodes - *antibiotic resistance* (826.5), *E. coli* (245.7), and *horizontal gene transfer* (410.4) - highlighting its pivotal role in connecting florfenicol research with broader public health concerns. (Supplementary file 1.).

Keyword map

The Keywords related to florfenicol research are presented in Figure 6A shows the overlay visualization, where keywords are displayed in gradient col-

DISCUSSION

Our bibliometric analysis reveals that florfenicol research has transformed from a niche veterinary topic into a multifaceted scientific domain spanning four decades. The remarkable 10.55% annual growth rate, culminating in 94 publications in 2024, reflects growing global awareness of antimicrobial resistance challenges and the environmental footprint of veterinary antibiotics. This exponential expansion, particularly post-2018, coincides with international policy initiatives addressing antimicrobial resistance and the United Nations' sustainable development goals targeting responsible antibiotic use (Aslam et al., 2024).

China's dominance, contributing 401 articles as corresponding author country, arises from its position as the world's largest aquaculture producer and significant livestock industry (Zhao et al., 2021). Chinese institutions have invested heavily in veterinary pharmaceutical research, creating specialized research centers that bridge agricultural universities and medical institutions.

The interdisciplinary spread across 367 sources demonstrates florfenicol's relevance beyond veterinary medicine. Environmental science journals' strong representation (Science of the Total Environment, Ecotoxicology and Environmental Safety) signals recognition that veterinary antibiotics represent emerging environmental contaminants. Similarly, analytical chemistry journals' prominence reflects the technical challenges of detecting florfenicol residues at increasingly stringent regulatory limits. This disciplinary diversity, averaging 6.14 co-authors per paper, suggests that addressing florfenicol-related challenges requires collaborative expertise spanning microbiology, chemistry, ecology, and veterinary science.

The evolution of florfenicol research exemplifies the One Health concept, recognizing interconnections between animal health, human health, and environmental integrity (Pitt and Gunn, 2024). Initially developed as a safer alternative to chloramphenicol for veterinary use (Trif et al., 2023a), florfenicol now represents a microcosm of broader antimicrobial resistance challenges (Zhang et al., 2022).

The geographic concentration of research, though indicative of strong regional expertise, also highlights notable gaps in global representation. Limited contributions from Africa and parts of Asia, where florfenicol use may be increasing without adequate monitoring, suggest potential blind spots in global resistance surveillance (Vernet et al., 2014). The strong China-USA collaboration axis, while productive, may inadvertently create research paradigms that don't fully address challenges in resource-limited settings where regulatory oversight and analytical capabilities differ substantially.

The emergence of advanced analytical techniques (molecularly imprinted polymers, LC-MS/MS) in recent publications (Bardhi et al., 2023) indicates that detection and monitoring capabilities are evolving to meet regulatory demands. However, the persistent focus on detection rather than prevention suggests that research priorities may be reactive rather than proactive, addressing contamination after occurrence rather than preventing initial environmental release.

Review of similar related studies reveals that florfenicol research has been investigated from therapeutic, environmental, and bibliometric perspectives. Trif et al. (2023a) provided a systematic review of florfenicol in veterinary medicine, highlighting its ribosome-targeting antibacterial action, anti-inflammatory effects, and formulation challenges, while suggesting nanotechnology-based approaches to enhance efficacy and overcome solubility issues (Trif et al., 2023a). Subbiah et al. (2011) reported that unlike many antibiotics which degrade in soil, florfenicol and β -lactams remain bioactive, raising concerns about environmental persistence and resistance dissemination (Subbiah et al., 2011). Similarly, a global bibliometric analysis of antimicrobial resistance in the environment emphasized the growing but still underrepresented role of environmental research within the One Health framework (Sweileh and Moh'd Mansour, 2020). However, the absence of previous bibliometric studies dedicated solely to florfenicol highlights the originality and importance of the current research.

In special emphasis on resistance, the florfenicol resistance in human pathogens may be attributed to horizontal transfer from animal origin (Lu et al., 2018). In addition, the incidence of resistance of chloramphenicol and florfenicol is proved to be more than the expected levels among bovine bacterial isolates (White et al., 2000). This necessitates strict regulatory measures to the application of the drug in veterinary practices.

Strengths and Limitations

This study's comprehensive approach, analyzing 972 publications across four decades, provides unprecedented insight into florfenicol research evolution. The use of multiple bibliometric indicators - from simple publication counts to sophisticated network centrality measures - offers multidimensional understanding of the research landscape.

However, reliance on Scopus alone may underrepresent research from institutions or countries with limited database coverage. Regional journals publishing in languages other than English might contain valuable research not captured in our analysis. The exclusion of grey literature, conference proceedings, and regulatory documents potentially overlooks practical applications

and policy-relevant findings. Additionally, bibliometric indicators measure quantity and formal impact but cannot assess research quality or practical implementation of findings.

CONCLUSION

This bibliometric analysis establishes florfenicol as a rapidly evolving research domain transitioning from veterinary therapeutic focus to environmental and resistance concerns. The field demonstrates strong international collaboration yet reveals geographic disparities requiring attention. Moving forward, we recommend establishing research networks linking high-output countries with underrepresented regions to ensure global coverage of resistance surveillance.

Future investigations should prioritize prevention strategies over detection methods, developing alternatives to florfenicol use and improving waste treatment technologies. Integration of bibliometric monitoring with resistance surveillance data could create early warning systems for emerging resistance patterns. Finally, interdisciplinary research teams should include social scientists and economists to address behavioral and economic drivers of antibiotic use, ensuring that technical solutions align with practical implementation possibilities.

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Author's Contribution

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Competing interest

The authors declare no conflict of interest.

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Supplementary Data

The supplementary material (Supplementary file 1) associated with this article is available online at the following permanent link:

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