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Antibiotic Residues in Broiler Meat: Challenges for Food Safety, Public Health, and Sustainable Broiler Farming Issues

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Abstract

Antibiotic residues in broiler meat pose significant risks to food safety, public health, and the sustainability of poultry farming. The use of antibiotics in broiler production, both for therapeutic and prophylactic purposes, has led to the accumulation of residues in meat, which can contribute to the development of antimicrobial resistance (AMR). This paper explores the various potential sources of antibiotic residues in broiler meat, including feed-related factors, water contamination, injection practices, environmental contamination, and management practices. It discusses how improper antibiotic use, inadequate withdrawal periods, cross-contamination, and non-compliance with regulatory guidelines exacerbate the presence of residues. Furthermore, the implications of antibiotic residues for food safety and public health, particularly the risks associated with AMR, are critically examined. The paper also highlights the importance of adopting sustainable poultry farming practices, such as improved management strategies, monitoring systems, and adherence to withdrawal periods, to mitigate the risks associated with antibiotic residues. Addressing these challenges is essential for ensuring the safety of poultry products, protecting public health, and promoting the long-term sustainability of poultry farming practices.

Keywords: Antibiotic Residues, Broiler Meat, Sustainable Broiler, Genetic Changes, Biosecurity Measures

INTRODUCTION

The use of antibiotics in broiler poultry production has long been a common practice, primarily aimed at preventing diseases, promoting growth, and improving overall productivity. However, this widespread use has raised significant concerns regarding the presence of antibiotic residues in broiler meat, which poses potential risks to food safety, public health, and the sustainability of the poultry industry. Antibiotic residues in meat are the result of incomplete metabolism or excretion of drugs used in animal husbandry, leading to trace amounts remaining in edible tissues [1]. This issue has garnered significant attention due to its potential implications for both human health and the broader agricultural sector.

These residues are of particular concern due to their association with the growing global issue of antimicrobial resistance (AMR), which occurs when bacteria develop resistance to drugs designed to kill them [2, 3]. The transfer of resistant pathogens from animals to humans through the consumption of contaminated meat, environmental exposure, or direct contact with animals presents a serious threat to public health [4]. Moreover, the accumulation of antibiotic residues in the environment can contribute to the broader problem

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of resistance, affecting ecosystems and animal health [5]. As the risks of AMR continue to escalate, the need for effective strategies to mitigate antibiotic residue contamination becomes ever more pressing.

Several potential sources contribute to the presence of antibiotic residues in broiler meat. These include the administration of antibiotics through medicated feed and drinking water, improper injection practices, and failure to adhere to recommended withdrawal periods [6]. Environmental contamination, such as residues in bedding or litter, and cross-contamination between medicated and non-medicated birds, further complicate the situation [7]. The implications of antibiotic residues go beyond human health risks; they also impact the sustainability of poultry farming practices. Growing consumer demand for antibiotic-free products and stricter regulatory measures create increasing pressure on poultry farmers to address this issue. This paper aims to provide a comprehensive overview of the potential sources of antibiotic residues in broiler meat, exploring their implications for food safety, public health, and the future of sustainable poultry production.

SOURCES OF ANTIBIOTIC RESIDUES

Feed-Related Sources

- *Medicated Feed Use:* Administering antibiotics through medicated feed for growth promotion or disease prevention can lead to residue accumulation in broiler meat [8]. If birds are not given sufficient time to clear the drugs from their systems before slaughter, these residues can persist in tissues, raising food safety concerns and potential health risks for consumers.
- *Feed Contamination:* Cross-contamination from improperly stored or handled medicated feed can result in unintended antibiotic exposure. Non-medicated feed may become contaminated with antibiotics during storage or handling, exposing broilers to these drugs inadvertently [9]. This accidental intake can lead to residues in meat, especially if withdrawal periods are not adequately observed before processing.
- *Antibiotic-contaminated Ingredients:* Feed ingredients such as animal by-products or fishmeal can contain residual antibiotics from previous applications. When these ingredients are included in broiler feed, antibiotics may be ingested by the birds, leading to accumulation in their tissues [10]. Without proper clearance, these residues can remain in the meat, impacting food safety and public health.
- *Inadequate Withdrawal Times:* Failure to observe appropriate withdrawal times after feeding medicated feed can result in antibiotic residues persisting in broiler meat [11]. If birds are not allowed sufficient time to metabolize or excrete these drugs, residues remain in their tissues, potentially reaching consumers and raising health risks associated with antibiotic exposure [12].
- *Recycled Feed:* The use of feed remnants or by-products containing residual antibiotics in subsequent batches can expose broilers to unintended doses of antibiotics [13]. When recycled feed containing residues is reintroduced, the birds may ingest these antibiotics, potentially leading to detectable residues in their meat, posing food safety risks if withdrawal periods are not maintained.

Water-Related Sources

- *Medicated Water Use:* The addition of antibiotics to drinking water for disease control or prevention exposes broilers to antibiotic residues [7]. If antibiotics are not completely metabolized or excreted before slaughter, they can accumulate in tissues [14]. This results in residues remaining in the meat, which can compromise food safety and public health if not properly managed with adequate withdrawal periods.
- *Incorrect Dosing in Water Systems:* Overdosing or underdosing antibiotics in water systems can result in improper antibiotic levels in broilers [15]. Overdosing increases the likelihood of antibiotic residues in meat, while underdosing may not effectively control infections [16]. Both scenarios can lead to unintended residue accumulation in tissues, posing risks to food safety and contributing to potential antimicrobial resistance if withdrawal times are not adhered to.
- *Water Contamination Risk:* Cross-contamination of non-medicated water with medicated water during farm operations can unintentionally expose broilers to antibiotics. When medicated water

mixes with non-medicated water, broilers ingest antibiotics they were not intended to receive [17]. This unintended exposure leads to antibiotic residues in the meat, which may pose risks to consumers, particularly if withdrawal periods are not properly observed before slaughter.

- *Inadequate Flushing of Water Lines:* Failure to flush out antibiotic residues from water lines after treatment can result in lingering antibiotics in the water system. When the antibiotic-laced water is consumed by broilers, residues accumulate in their tissues [18]. If these residues are not cleared before slaughter, they may be transferred into the meat, posing food safety concerns for consumers.

Medication Practices

- *Injectable Antibiotics:* Injecting antibiotics directly into broilers for therapeutic purposes can lead to residues in meat if withdrawal periods are not followed [19]. Antibiotics administered via injection are metabolized slowly, and without proper clearance time, they can accumulate in the tissues, increasing the risk of residues remaining in the meat and affecting food safety [20].
- *Incorrect Dosing of Antibiotics:* Errors in the administration of antibiotics, such as incorrect dosages, can result in improper drug levels in broiler tissues [21]. Overdosing may cause excessive residues, while underdosing may not effectively treat infections, leading to the need for further treatments and a higher risk of residues in meat if withdrawal times are not strictly adhered to [22].
- *Depot or Slow-Release Antibiotics:* Depot or slow-release antibiotics are designed to be administered over extended periods, releasing the drug gradually into the broiler's system [23]. These antibiotics can accumulate in tissues over time, and without adequate withdrawal periods, residues can persist in the meat, posing food safety concerns for consumers due to prolonged exposure to antibiotic residues.
- *Injection Site Contamination:* Antibiotic residues can accumulate at the injection site, leading to higher concentrations of drugs in the broiler's meat [24]. This localized accumulation can result in detectable antibiotic residues in the meat, which may not be uniformly distributed, posing risks for consumers if these residues exceed allowable levels and withdrawal periods are not followed.
- *Expired or Off-Label Antibiotics:* The use of expired or off-label antibiotics can result in residues that are harder to clear from broiler tissues [25]. These drugs may have extended half-lives, meaning they stay in the system longer than expected, leading to increased chances of antibiotic residues remaining in the meat if proper withdrawal times are not observed, affecting food safety.
- *Multiple Doses of Antibiotics:* Administering multiple doses of antibiotics to broilers, particularly if done incorrectly, can lead to the accumulation of residues in their tissues [26]. Repeated treatments increase the chances of residues building up, and without adequate time for the birds to clear the drugs, these residues may persist in the meat, posing potential risks to consumer health.

Environmental Sources

Contaminated Bedding Materials

Bedding materials, such as straw or wood shavings, may be contaminated with antibiotic residues from manure or leftover medicated feed. If broilers come into contact with or ingest contaminated bedding, they can absorb these residues into their system [27]. This exposure can lead to the accumulation of antibiotics in meat, raising concerns for food safety if withdrawal periods are not followed.

Contaminated Litter

Poultry litter, which includes manure and leftover feed, can contain antibiotic residues if antibiotics have been used in the farm [28]. When broilers ingest or come into direct contact with contaminated litter, they may absorb these residues, which can accumulate in their tissues. If the birds are not allowed adequate time to clear these residues, they may remain in the meat.

Soil and Water Contamination

Antibiotic residues from nearby agricultural fields or water bodies can contaminate poultry farms through runoff or irrigation [29]. When the farm's water or soil becomes tainted with antibiotics, broilers

may ingest or absorb these residues, leading to potential accumulation in their meat [30]. This environmental contamination can make it difficult to control the antibiotic levels in broiler meat.

Airborne Antibiotic Particles

Aerosols or dust particles containing antibiotic residues may be suspended in the air due to the application of antibiotics in farm environments [31]. These particles can settle on broilers, their feed, or water, potentially leading to inadvertent ingestion. Over time, these residues can accumulate in tissues, contributing to antibiotic residues in meat if not cleared before slaughter.

Cross-Contamination from Neighboring Farms

Residues from neighboring farms using antibiotics can cross-contaminate shared infrastructure, such as transport vehicles or water systems. Antibiotic residues from nearby farms can spread through direct contact or shared environmental factors, exposing broilers to unintended antibiotics [32]. This exposure can result in residues in the meat, posing food safety risks if proper withdrawal periods are not respected.

Management Practices

Non-Compliance with Withdrawal Periods

Slaughtering broilers before the full withdrawal period for antibiotics has elapsed results in antibiotic residues remaining in their meat [11]. Antibiotics require time to be metabolized and excreted by the birds; failing to respect this period increases the likelihood that residues will persist, posing risks to food safety and public health if the meat is consumed before proper clearance [32].

Poor Record-Keeping

Inaccurate tracking of antibiotic use can lead to errors in determining proper withdrawal times or history of treatment. Without clear documentation, farmers may unknowingly slaughter birds before the antibiotics have fully cleared from their system, resulting in antibiotic residues in the meat [33]. This oversight compromises food safety and increases the risk of consumer exposure to harmful residues.

Lack of Monitoring Systems

Insufficient monitoring of antibiotic use on farms can lead to improper administration or overuse of antibiotics [32]. Without proper oversight, there is a higher likelihood of incorrect dosing or failure to adhere to recommended withdrawal periods [34]. This mismanagement can lead to excessive antibiotic residues accumulating in broiler meat, raising concerns for food safety and public health.

Unregulated Use of Antibiotics

The use of antibiotics without proper regulation or oversight, including unauthorized or off-label use, can significantly increase the risk of antibiotic residues in broiler meat [35]. Unregulated use may involve higher doses, incorrect administration methods, or the use of drugs not approved for poultry, leading to a buildup of residues that may pose food safety and public health risks if not properly managed [36].

Failure to Adhere to Guidelines

Non-compliance with veterinary recommendations or established guidelines for antibiotic use can lead to improper drug administration and excessive residues in broiler meat [30]. Without following prescribed protocols, broilers may receive antibiotics inappropriately, resulting in drug accumulation in tissues. This failure to adhere to guidelines increases the likelihood of antibiotic residues persisting in meat, affecting consumer safety.

GENETIC AND PHYSIOLOGICAL FACTORS

Individual Variation in Metabolism

Genetic differences among broilers can influence how quickly they metabolize and excrete antibiotics. Some birds may process antibiotics more efficiently, while others may accumulate higher residues due to slower metabolism [37]. These variations can lead to inconsistent antibiotic levels in

meat, with certain birds exhibiting higher residue concentrations, potentially compromising food safety and public health if not carefully managed.

Health Status of Birds

Sick broilers may metabolize antibiotics more slowly than healthy birds, resulting in higher concentrations of residues in their tissues. When broilers are ill, their physiological processes, including drug absorption and excretion, may be impaired [38]. This delayed metabolism can lead to antibiotic residues remaining in their meat, increasing the risk of consumer exposure to these drugs if withdrawal periods are not adequately followed.

Growth Rate of Birds

Broilers with rapid growth rates may experience slower antibiotic metabolism, leading to higher residue levels in their tissues [39]. Rapid growth demands significant physiological resources, potentially interfering with the bird's ability to process and eliminate antibiotics efficiently. As a result, antibiotic residues may persist in their meat, posing food safety concerns if the birds are slaughtered before the drugs are fully cleared.

CROSS-CONTAMINATION AND EQUIPMENT ISSUES

Contaminated Equipment

Tools, utensils, or containers used for administering antibiotics or medicated feed that are not properly cleaned can transfer residues between batches of birds [40]. Contaminated equipment may carry trace amounts of antibiotics, which can contaminate non-medicated birds, leading to antibiotic residues in their meat [41]. This cross-contamination increases the likelihood of residues, even if proper antibiotic use protocols are followed.

Shared Equipment Between Farms

When equipment such as transport vehicles, feeders, or water systems is shared between farms with both medicated and non-medicated birds, the risk of cross-contamination increases [9]. Residues from medicated birds can transfer to non-medicated birds, leading to antibiotic residues in the meat of otherwise untreated birds. Shared equipment should be properly sanitized to prevent this type of contamination.

Inadequate Cleaning of Injection Equipment

Using unsterilized syringes or needles between birds can lead to the transfer of antibiotic residues. If the injection equipment is not properly cleaned or sterilized between uses, residues from treated birds can be passed on to untreated birds, contaminating them [42]. This practice increases the risk of antibiotic residues in meat, highlighting the importance of maintaining strict hygiene protocols on the farm.

Storage and Handling Practices

Improper Storage of Antibiotics

Storing antibiotics in unsuitable conditions, such as excessive heat or humidity, can cause the drugs to degrade or lose efficacy [43]. Degraded antibiotics may result in improper dosing, which can leave higher or inconsistent residues in broiler meat [44]. Proper storage conditions are essential to maintain antibiotic stability and effectiveness, minimizing the risk of residues in poultry products.

Improper Disposal of Antibiotics

Failure to dispose of unused or expired antibiotics correctly can lead to environmental contamination or accidental ingestion by birds [45]. Improper disposal methods, such as dumping antibiotics in open areas or water systems, can contaminate the farm environment, allowing birds to inadvertently consume these drugs [46]. This can result in antibiotic residues in the meat, posing food safety risks.

Contamination During Transport

Antibiotics that are not securely sealed during transport can leak into the surrounding environment or other products. If antibiotics come into contact with poultry feed, water, or broilers during transportation, residues may transfer to the birds [10]. Ensuring that antibiotics are properly sealed and stored during transit is crucial to preventing accidental contamination and the subsequent buildup of residues in broiler meat.

External Contaminants

Antibiotic Residues in Imported Ingredients

Imported animal feeds or feed ingredients from countries with different regulatory standards may contain antibiotic residues [40]. Variations in global regulations mean that some countries may use antibiotics more liberally, leading to residues in imported feed components. These residues can transfer to broilers, resulting in higher antibiotic concentrations in meat, which may pose food safety risks in regions with stricter standards.

Use of Unapproved Additives

The use of non-approved antibiotic additives or contamination from suppliers using substandard practices can introduce antibiotic residues into broiler meat [47]. Some feed suppliers may use unregulated or unauthorized antibiotics to promote growth or prevent disease in animals, which can result in the presence of residues in animal products [48]. Such practices compromise meat safety and can lead to violations of food safety regulations.

ANTIBIOTICS IN THE FARM INFRASTRUCTURE

Residues in Poultry Houses

Antibiotic residues may linger in poultry housing environments, such as on surfaces, equipment, or in the air, leading to inadvertent ingestion by birds. Residues can accumulate from the use of antibiotics in feed or water and remain in the environment [36]. When birds ingest contaminated bedding or dust, they can accumulate antibiotic residues in their tissues, impacting meat safety [49].

Cross-contamination Through Waste Disposal

Manure or dead birds containing antibiotic residues can contaminate other areas on the farm if not properly managed [50], [51]. Improper waste disposal practices, such as spreading manure with antibiotic residues on fields or dumping dead birds in unregulated areas, can result in environmental contamination [28]. This cross-contamination increases the risk of residues entering the poultry production system and affecting meat quality.

ANTIBIOTIC USE IN POULTRY PRODUCTION

Historical Context of Antibiotic Use

The use of antibiotics in poultry farming dates back to the mid-20th century when they were initially introduced to prevent disease and promote growth [52]. Over time, their use expanded as a routine practice in broiler production, significantly increasing poultry yields. This widespread use, however, also raised concerns about antibiotic residues in meat and resistance development.

Purpose of Antibiotics in Broiler Production

Antibiotics are used in broiler farming primarily for disease prevention, control of infections, and growth promotion. These substances help maintain healthy flocks, improve feed conversion, and enhance productivity [53], [54]. Antibiotics can also address challenges like respiratory or intestinal diseases, improving overall poultry health and reducing mortality rates, though their use has sparked debates on food safety and public health risks [55].

Regulatory Frameworks and Guidelines

Antibiotic use in poultry is regulated by authorities such as the FDA, EFSA, and WHO, which set guidelines to limit residues in meat [56]. Regulations ensure that antibiotics used in poultry meet safety

standards, including prescribed withdrawal periods before slaughter. These guidelines aim to safeguard consumers from harmful residues and mitigate the risk of antimicrobial resistance, balancing industry needs and food safety.

Trends in Antibiotic Usage

Over recent decades, global antibiotic usage in poultry has fluctuated, influenced by regulatory shifts, consumer demand, and public health concerns [57]. In some regions, stricter regulations have reduced antibiotic use, while others still rely heavily on these drugs. Growing awareness about antimicrobial resistance has driven efforts to reduce antibiotics' role in poultry farming, promoting sustainable, antibiotic-free alternatives.

FOOD SAFETY AND PUBLIC HEALTH

Risks Associated with Antibiotic Residues

Antibiotic residues in broiler meat pose potential health risks to consumers, including allergic reactions, toxicity, and the accumulation of harmful chemicals in the body [58]. In some cases, residues may cause adverse effects such as gastrointestinal disturbances or skin reactions [14]. These risks emphasize the need for rigorous monitoring and control to ensure the safety of poultry products in the food supply.

Contribution to Antimicrobial Resistance (AMR)

The presence of antibiotic residues in meat contributes significantly to the global problem of antimicrobial resistance (AMR) [59]. Residues can encourage the development of resistant bacteria in humans, making infections harder to treat [60]. This phenomenon occurs when bacteria adapt to the antibiotics, reducing their effectiveness in treating diseases, thereby complicating future medical treatments and increasing the risk of untreatable infections.

Pathways of Human Exposure to AMR

Humans can be exposed to antibiotic-resistant bacteria through the consumption of contaminated broiler meat [61]. Pathogens resistant to antibiotics may transfer to humans via ingestion, food handling, or cross-contamination during preparation [62]. In some cases, resistant bacteria can colonize the human gut, leading to infections that are difficult to treat with standard antibiotics, further exacerbating the public health threat posed by AMR [63].

Economic and Public Health Implications

The economic burden of antimicrobial resistance (AMR) is substantial, leading to higher healthcare costs, prolonged hospital stays, and more intensive treatment regimens [64, 65]. Public health implications are profound, as AMR reduces the effectiveness of antibiotics in treating infections, increasing mortality and morbidity rates [66]. The increased cost of treating resistant infections also places a financial strain on health systems and society at large.

Regulatory and Safety Standards

Regulatory frameworks for antibiotic residues in broiler meat, such as those set by the FDA, EFSA, and WHO, are essential to safeguard public health [67]. These standards define acceptable residue levels and withdrawal periods, ensuring that meat products are safe for consumption. Strict enforcement of these regulations is vital in minimizing risks, protecting consumers from antibiotic residues, and mitigating the rise of antibiotic-resistant bacteria.

SUSTAINABILITY CHALLENGES IN BROILER FARMING

Environmental Impact of Antibiotic Residues

Antibiotic residues in broiler farming contribute to environmental contamination, particularly in soil and water. Runoff from farms can carry residues into nearby ecosystems, affecting aquatic life and soil health [49], [68]. Over time, these residues can accumulate, leading to long-term ecological damage

and further promoting the development of antimicrobial-resistant bacteria in the environment, which poses a broader environmental health risk [3].

Effects on Animal Welfare and Farm Productivity

Overuse of antibiotics in broiler farming can negatively impact animal welfare, leading to health issues such as immune suppression and antibiotic resistance [69]. Furthermore, heavy reliance on antibiotics may reduce farm productivity in the long term, as it may require increased antibiotic use or lead to disease outbreaks. Maintaining animal health through sustainable practices can mitigate these effects and improve productivity.

Pressure From Consumers and Regulatory Bodies

Consumers and regulatory bodies are increasingly demanding antibiotic-free poultry products due to concerns over food safety, public health, and animal welfare [70]. This shift in consumer preferences is pushing the poultry industry toward adopting more sustainable farming practices. The growing awareness of antibiotic residues and their implications for human health places pressure on producers to transition to alternative, more responsible methods of production.

Challenges in Transitioning to Sustainable Farming Practices

Transitioning to sustainable farming practices without antibiotics presents challenges, including higher production costs, the need for specialized knowledge, and the development of new disease control strategies [71]. Poultry farmers must invest in alternative approaches such as probiotics, vaccination programs, and improved farm management systems, while also maintaining profitability [72]. These challenges require support from both policy and research to ensure a successful shift to antibiotic-free systems.

The Role of Antibiotic Stewardship

Antibiotic stewardship plays a crucial role in promoting sustainable poultry farming by ensuring that antibiotics are used responsibly and only when necessary [73]. Implementing stewardship programs helps reduce antibiotic use, prevents resistance development, and ensures that antibiotics remain effective for human health. This approach, combined with alternative disease management strategies, can support the long-term sustainability of broiler production while protecting public health [74].

STRATEGIES TO MITIGATE ANTIBIOTIC RESIDUES

Development of Monitoring and Testing Methods

The development of advanced monitoring and testing methods is critical to detecting antibiotic residues in broiler meat. Implementing regular, comprehensive testing ensures that antibiotic levels remain within safe limits. Innovations such as rapid testing technologies and real-time monitoring systems can improve the effectiveness of residue detection, ensuring compliance with safety standards and reducing risks to public health from contaminated meat [75].

Best Practices in Feed and Water Management

Implementing best practices in feed and water management is essential to minimize antibiotic residues. This includes ensuring proper storage, accurate dosing, and adequate flushing of water systems to prevent residue accumulation [76]. Additionally, maintaining a clear separation between medicated and non-medicated feed and water helps to reduce cross-contamination, ultimately lowering the likelihood of antibiotic residues in broiler meat.

Alternative Disease Management Strategies

Alternative disease management strategies, such as the use of probiotics, vaccines, and non-antibiotic growth promoters, offer sustainable solutions to reduce reliance on antibiotics [77]. These strategies can help improve overall animal health, reduce the incidence of disease, and enhance performance without the negative effects of antibiotics. Promoting these alternatives contributes to healthier poultry and safer meat production, minimizing the risk of antibiotic residues.

Improved Sanitation and Biosecurity Measures

Enhancing sanitation and biosecurity measures on poultry farms is vital to reduce the risk of contamination. Proper cleaning and disinfecting of equipment, housing, and water systems can prevent the spread of antibiotic-resistant bacteria [78]. Strengthening biosecurity protocols, including restricting farm access and controlling the movement of animals, reduces disease transmission and minimizes the need for antibiotics, decreasing the potential for residue contamination [79].

Advancements in Genetic Research

Advancements in genetic research have the potential to create disease-resistant poultry, reducing the need for antibiotics [80]. By breeding poultry with enhanced immune responses or greater resistance to specific pathogens, the reliance on antibiotic treatments can be significantly reduced [81]. These innovations support more sustainable poultry production by addressing the root causes of disease, which would otherwise require antibiotic interventions, helping reduce residue risks.

Strengthening Regulatory Frameworks

Strengthening regulatory frameworks and compliance mechanisms is crucial to minimizing antibiotic residues in broiler meat. Establishing clear, enforceable guidelines for antibiotic use, withdrawal periods, and residue testing ensures consistent practices across the poultry industry [82]. Regular inspections and penalties for non-compliance incentivize responsible antibiotic use, fostering a more sustainable approach to poultry farming while ensuring meat safety for consumers.

Public Awareness and Education

Raising public awareness and educating consumers and farmers on the responsible use of antibiotics in agriculture is essential to promoting sustainable practices [32]. By informing stakeholders about the risks of antibiotic residues and antimicrobial resistance, individuals can make more informed decisions about their food choices [83]. Education campaigns can also encourage demand for antibiotic-free poultry products, supporting healthier farming practices and better consumer health outcomes.

CONCLUSIONS

The presence of antibiotic residues in broiler meat presents significant challenges to food safety, public health, and the sustainability of poultry farming practices. The various sources of these residues, from feed and water-related factors to improper management practices and environmental contamination, highlight the complexity of the issue. As antimicrobial resistance continues to pose a global health threat, it is imperative to strengthen regulatory frameworks, improve farming practices, and ensure compliance with withdrawal periods to minimize residue contamination. Collaborative efforts across stakeholders, including farmers, policymakers, and researchers, are essential to safeguard both human health and the long-term viability of the poultry industry. Moving towards more sustainable, antibiotic-free production systems will not only protect consumer health but also enhance the reputation and competitiveness of the broiler industry on the global stage.

Future Directions

Future research should focus on developing more effective methods for monitoring and detecting antibiotic residues in broiler meat, enhancing food safety. Improved surveillance systems and regular testing are essential to ensure compliance with withdrawal periods and prevent residue accumulation. Additionally, disease management strategies like the use of probiotics, vaccines, and non-antibiotic growth promoters must be emphasized to reduce antibiotic reliance in broiler farming, promoting alternative approaches that maintain poultry health while mitigating the risks associated with antibiotic overuse and its negative effects on both human health and poultry production systems.

There is a need to explore advanced farming practices that reduce contamination risks, including improved hygiene protocols, waste management systems, and feed storage. Research should also focus on the environmental impact of antibiotic residues, particularly their persistence in farm infrastructure, bedding, and water systems, to better understand and mitigate cross-contamination. Incorporating

genetic advancements to develop disease-resistant poultry will offer long-term solutions, reducing the need for antibiotics. Additionally, studying the impact of various antibiotics on broiler gut health and the microbiome will provide insights into residue levels in meat, ensuring safer poultry products.

International collaboration and harmonization of regulatory standards are crucial for addressing antibiotic use in poultry farming. Global consistency in antibiotic use will ensure more effective strategies to combat antimicrobial resistance. Public awareness campaigns and consumer education can also help shift demand towards sustainable, antibiotic-free poultry products. Additionally, ongoing research into alternative feed ingredients and more sustainable poultry farming practices is vital. These efforts will contribute to reducing reliance on antibiotics, fostering a safer, more sustainable approach to broiler production, and ultimately improving public health outcomes.

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