

Review

Sustaining the boom: the critical role of safe and sustainable technology in Bangladesh's broiler industry

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Abstract: The broiler industry in Bangladesh has grown rapidly from small backyard farms into a major commercial sector, helping to meet the country's growing demand for protein. However, this fast expansion has also brought challenges, including frequent disease outbreaks, rising antimicrobial resistance (AMR), and environmental impacts from intensive farming. Diseases like Avian Influenza (AI) and Newcastle Disease (ND) often lead to the overuse of antibiotics, contributing to the emergence of multidrug-resistant bacteria and antibiotic residues in poultry products, which pose risks to public health. At the same time, waste management and other environmental pressures from large-scale production add further strain. This review not only highlights these problems but also explores practical solutions. Measures such as improved biosecurity, targeted vaccination, and scientifically-supported alternatives to antibiotics—like probiotics, prebiotics, and plant-based feed additives—can help maintain productivity while reducing health and environmental risks. The approach is framed within a "One Health" perspective, recognizing the close links between animal, human, and environmental health. The future of the broiler industry in Bangladesh depends on adopting sustainable, integrated practices. This requires stronger policy enforcement, farmer education, investment in local research and development, and collaboration through public-private partnerships. By following this roadmap, stakeholders can transform the sector into a safer, more sustainable industry that protects public health, supports farmers, and ensures long-term food security. This review provides a critical evidence base and a strategic framework for policymakers, industry leaders, and researchers to collaboratively transform the Bangladeshi broiler sector into a model of sustainable and safe production.

Keywords: antimicrobial resistance; One Health; biosecurity; alternatives to antibiotics; food security

1. Introduction

The agricultural fabric of Bangladesh has been profoundly reshaped over the past three decades by the ascent of its poultry sector, with the broiler industry emerging as its most dynamic component. This evolution from a scattered, subsistence-level activity to a concentrated, commercial powerhouse represents one of the most significant success stories in the country's livestock domain (Akhter *et al.*, 2018). More importantly, it has been

instrumental in ameliorating the nation's chronic protein deficiency, making affordable animal protein accessible to a vast segment of the population and contributing to improved nutritional outcomes. The engine of this "poultry revolution" has been the rapid intensification of production systems. The adoption of high-density housing, genetically improved fast-growing bird strains, and commercial feed formulations has enabled unprecedented economies of scale and output. However, this very model of intensification has inadvertently cultivated a precarious ecosystem fraught with new risks. The high-stocking densities characteristic of these systems act as a chronic stressor, suppressing avian immune competence and creating ideal conditions for the rapid transmission and propagation of pathogens (Conan *et al.*, 2024). This has led to the endemicity of devastating infectious diseases, most notably Highly Pathogenic Avian Influenza (HPAI) and Newcastle Disease (ND), which have periodically caused catastrophic economic losses, eroded farmer livelihoods, and disrupted market stability.

Parallel to the public health emergency, the environmental externalities of intensive broiler farming are accumulating at an alarming rate. The management of poultry litter, a voluminous by-product of production, remains largely unscientific. Much of this waste is either indiscriminately dumped or applied raw to agricultural land, leading to the leaching of nitrates into groundwater, the runoff of phosphorus into surface waters causing eutrophication, and the emission of potent greenhouse gases like ammonia and nitrous oxide. Furthermore, the pursuit of maximum productivity has raised legitimate concerns regarding animal welfare, with issues such as footpad dermatitis, skeletal disorders, and heat stress prevalent in poorly managed, high-density systems (Dhama *et al.*, 2015; Chowdhury *et al.*, 2022).

These multifaceted challenges are not isolated; they are deeply interconnected, creating a vicious cycle that threatens the very foundation of the industry. This complex scenario underscores the urgent necessity for a fundamental paradigm shift—from a narrow focus on production volume at any cost to a holistic approach that embraces safety, sustainability, and the principles of "One Health." The One Health concept, which recognizes the intimate and inextricable linkages between the health of people, animals, and ecosystems, provides the only coherent framework for addressing these intertwined crises (Robinson *et al.*, 2016; Mackenzie and Jeggo, 2019). Therefore, this comprehensive review aims to systematically assess the current status, structural dynamics, and principal challenges of Bangladesh's broiler industry, while critically evaluating existing and emerging technological and managerial interventions to enhance its productivity, safety, and sustainability. It further seeks to synthesize compelling evidence on the drivers and impacts of AMR and to propose a viable pathway for reducing antimicrobial dependency through effective alternatives. The review also discusses the requisite policy, educational, and economic frameworks necessary to facilitate a widespread transition towards sustainable practices. The objective is to provide a strategic set of evidence-based recommendations for all stakeholders to ensure the long-term resilience, economic viability, and social license of this vital sector. This review underscores that coordinated, science-based improvements in antibiotic use, biosecurity, waste management, and sustainable technologies are essential to safeguard public health, protect the environment, and strengthen the long-term resilience of Bangladesh's broiler industry.

2. Methods and Materials

2.1. Search strategy

This study was designed as a broad narrative review to bring together and summarize what is currently known about the broiler industry in Bangladesh, focusing on safety, sustainability, and technology. To gather reliable information, we used a clear and structured search process. Most of the scientific articles were found through Google Scholar, while Bangladesh-based journals were searched to include local studies and grey literature. We also reviewed reports and online resources from major national institutions such as Bangladesh Agricultural University (BAU), the Bangladesh Livestock Research Institute (BLRI), and the Department of Livestock Services (DLS). All collected references were organized and checked using Zotero to ensure proper management and to remove duplicates.

The search strategy used a set of keywords combined with Boolean operators to capture the most relevant studies. The main search terms were: ("broiler industry" OR "poultry production") AND ("Bangladesh") AND ("antimicrobial resistance" OR "AMR" OR "antibiotic use") AND ("sustainability" OR "One Health") AND ("biosecurity" OR "vaccination") AND ("alternative to antibiotics" OR "probiotic" OR "prebiotic" OR "phytogenic") AND ("waste management" OR "litter management") AND ("disease" OR "Avian Influenza" OR "Newcastle Disease"). These terms were combined in different ways to ensure wide coverage of literature relevant to the broiler sector in Bangladesh.

2.2. Inclusion and exclusion criteria

A clear set of inclusion and exclusion criteria was used to select the literature. We included peer-reviewed research articles, systematic reviews, meta-analyses, case reports, government documents, reports from international agencies (FAO, WHO, WOA), and high-quality academic theses published between 2000 and 2025. Studies were selected if they were conducted in Bangladesh or provided findings directly relevant to the Bangladeshi broiler industry (Figure 1). We excluded articles not available in English or Bengali, opinion pieces without scientific evidence, editorials without primary data, and studies unrelated to the main topics of this review.

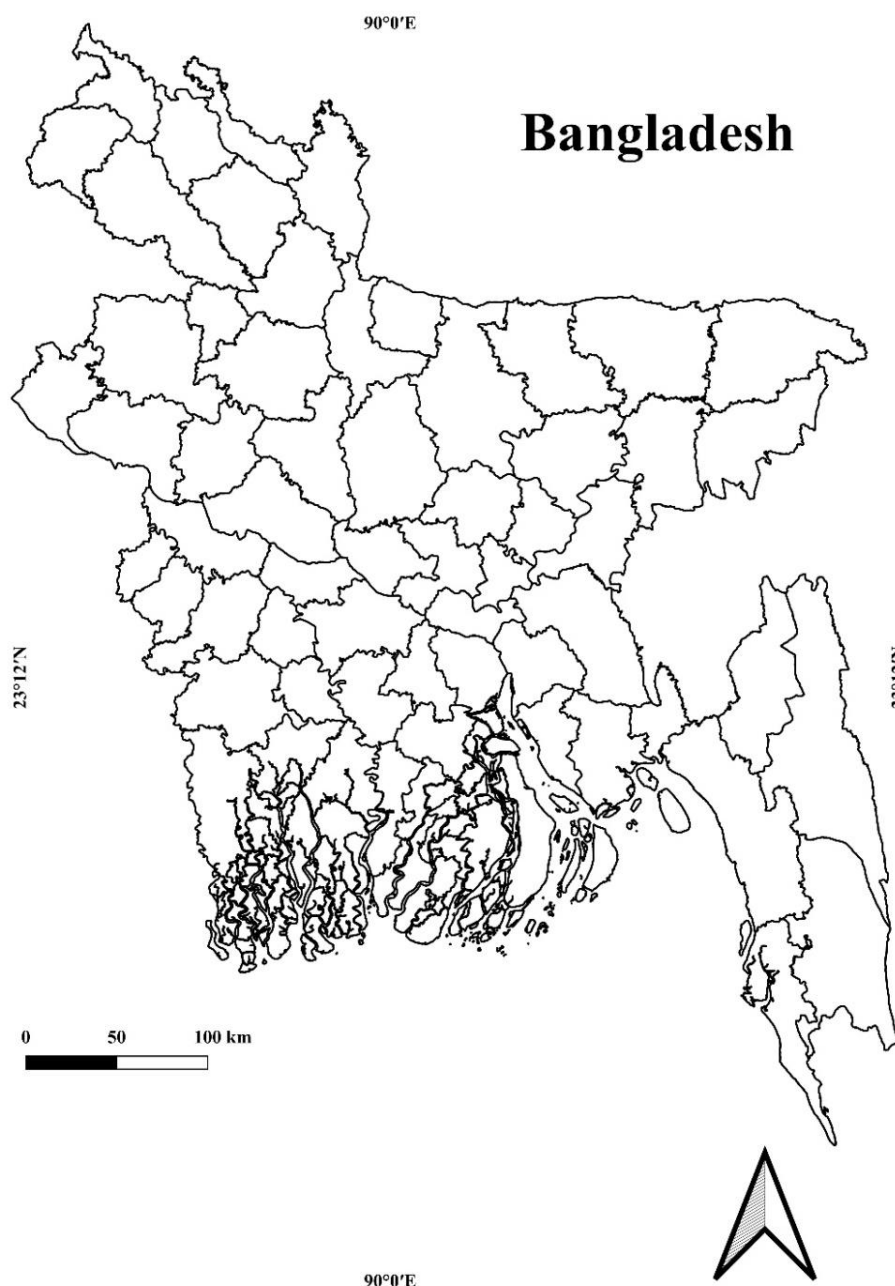


Figure 1. The literature was conducted research published from Bangladesh.

2.3. Data extraction and synthesis

Data from the selected literature were extracted into a standardized template designed to capture key information systematically. The extracted data included: study objectives, methodology (e.g., sample size, study design), key findings pertaining to disease prevalence, antibiotic usage patterns, AMR profiles, efficacy of technological interventions, and economic or environmental impact assessments.

2.4. Thematic analysis

Because the included sources varied widely—from quantitative studies to qualitative reports—a thematic analysis was used to organize and interpret the findings. All extracted information was coded and grouped into major themes, including “Structural Dynamics of the Industry,” “The AMR Cascade,” and “The Toolbox of Sustainable Interventions.” These themes shaped the structure of the next sections, ensuring a clear, logical, and critical presentation of the evidence (Figure 2).

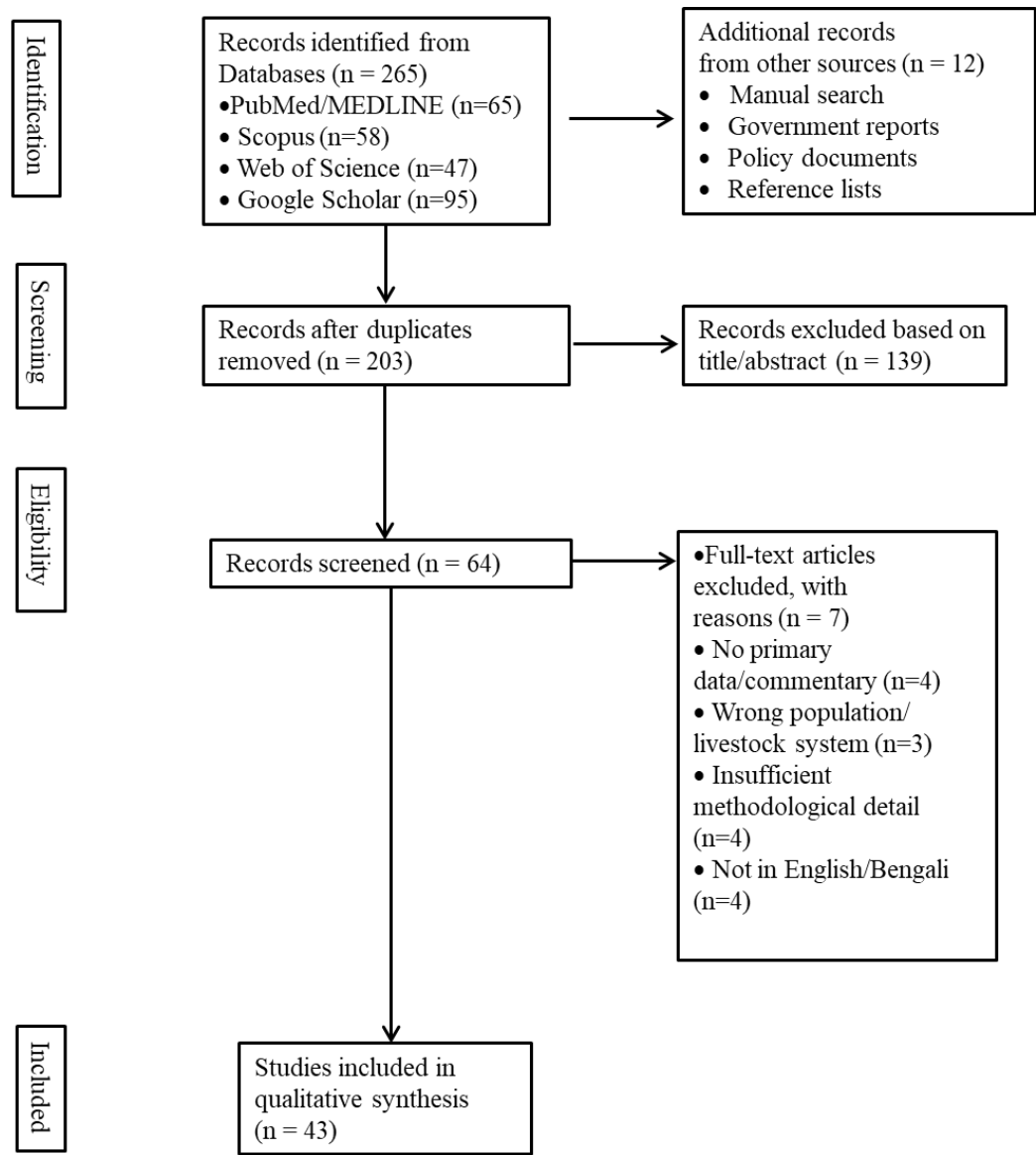


Figure 2. PRISMA flow diagram showing the four-stage study selection process: identification, screening, eligibility, and inclusion.

3. Industry structure, health challenges, AMR dynamics, environmental impacts, and mitigation pathways

3.1. Structure and operational realities of the Bangladeshi broiler industry

The Bangladeshi broiler industry presents a picture of stark contrasts, defined by a dualistic structure. On one end of the spectrum exists a growing segment of large, vertically integrated corporations. These entities exercise control over multiple stages of the production chain, including grandparent and parent stock operations, hatcheries, feed manufacturing, and commercial grow-out farms (Alam *et al.*, 2020a). This integrated model allows for the implementation of standardized operating procedures, centralized disease management, and a degree of advanced biosecurity that is difficult to achieve in fragmented systems. Conversely, and forming the overwhelming numerical majority, are thousands of small-scale (holding 500-2000 birds) and medium-scale (2000-5000 birds) farmers (Alam *et al.*, 2020b). These non-integrated producers are the backbone of the

industry, accounting for an estimated 70-80% of the total broiler production. These farmers operate within a context of severe constraints, including limited access to capital, precarious profit margins, and a high degree of vulnerability to external shocks such as disease outbreaks and sudden price fluctuations in day-old chicks and feed (Ali *et al.*, 2020). The supply chain that connects these producers to consumers is notably complex and fragmented. It typically involves a long sequence of intermediaries: from the feed dealer who often also provides veterinary advice, to the bird trader, to the wholesaler at the live bird market, and finally to the retailer. This fragmentation introduces significant inefficiencies; increases transaction costs, and, most critically, elevates the risk of disease transmission through the constant mixing of birds from multiple sources at various points along the chain (Chowdhury *et al.*, 2021). The lack of cold chain infrastructure and modern processing facilities further exacerbates these challenges, forcing a reliance on live bird markets that are recognized as hotspots for zoonotic pathogen amplification.

3.2. Major infectious disease pressures and their implications for broiler production

Infectious diseases pose a major threat to the productivity and economic stability of broiler farming in Bangladesh. Avian Influenza (AI), particularly HPAI H5N1, has persisted since 2007, causing the culling of millions of birds, direct economic losses in the hundreds of millions of dollars, and trade restrictions. The virus remains endemic, with live bird markets acting as key sites for viral maintenance and reassortment, and sporadic outbreaks continue to undermine consumer confidence and local markets. The ND, while less headline-grabbing, is the most economically significant disease for most smallholders, with velogenic strains causing mortality rates up to 100% in unvaccinated flocks. Although effective vaccines exist, improper storage, irregular schedules, incorrect administration, and poor farmer awareness compromise their efficacy, resulting in repeated outbreaks and substantial economic hardship (Kapczynski *et al.*, 2013).

Other infectious diseases also impact flock performance and profitability. Infectious Bursal Disease (Gumboro) weakens immunity, making birds susceptible to secondary infections, while chronic respiratory diseases caused by pathogens like *Mycoplasma gallisepticum* and *E. coli* reduce growth and feed efficiency. Foodborne zoonotic pathogens are of particular concern, with *Salmonella* detected in over 35% of broiler cloacal samples from live bird markets, many showing multidrug resistance, and *Campylobacter* prevalence is also high (Tresha *et al.*, 2021). This heavy pathogen load in market environments creates a significant risk for bacterial transmission from poultry to humans, posing a direct public health threat.

3.3. Escalating antimicrobial misuse and resistance

The relentless pressure from infectious diseases has fostered an industry culture heavily reliant on antimicrobials as a primary risk-management tool. This dependency is the principal driver of the escalating AMR crisis. Empirical studies and farm surveys consistently reveal a disturbing pattern of antibiotic use. Medications are frequently administered from the first day of life, not in response to diagnosed illness, but as a routine prophylactic or metaphylactic measure. Classes such as fluoroquinolones (e.g., enrofloxacin), tetracyclines, and polymyxins (e.g., colistin) are among the most commonly used (Das *et al.*, 2020a; Khatun *et al.*, 2020; Anaruzzaman *et al.*, 2021; Islam *et al.*, 2021; Hossain *et al.*, 2021). A critical factor underpinning this misuse is the lack of professional veterinary oversight. A significant proportion of farmers rely on advice from feed dealers, sales representatives from pharmaceutical companies, or fellow farmers, rather than on diagnoses from qualified veterinarians. This practice of using antibiotics as "insurance" against disease is a fundamental misuse that exerts immense selective pressure for resistance.

The consequences of this selective pressure are unequivocally visible in the laboratory. Surveillance studies conducted in various regions of Bangladesh consistently report alarmingly high rates of AMR in bacterial isolates from poultry. Over 75% of *E. coli* isolates from broilers were multidrug-resistant (resistant to three or more classes of antimicrobials) (Hossain *et al.*, 2025). Resistance rates to commonly used drugs like ampicillin, tetracycline, and trimethoprim-sulfamethoxazole frequently exceed 70%. Of utmost concern is the detection of resistance to critically important antimicrobials for human medicine. Fluoroquinolone resistance is common, and perhaps most worryingly, the plasmid-mediated colistin resistance gene (**mcr-1**), which confers resistance to a last-resort antibiotic, has been identified in poultry populations across the country, with a recent longitudinal study noting a worrying increase in its prevalence (Islam *et al.*, 2020). This signifies that a crucial line of defense in human medicine is being compromised by practices in animal production.

The problem extends beyond resistant bacteria to the drugs themselves. Studies analyzing broiler meat samples from retail markets have consistently found detectable residues of various antibiotics. Residues of fluoroquinolones in 22% and tetracyclines in 18% of samples tested, with a portion of these exceeding the internationally established Maximum Residue Limits (MRLs) (Bhuiyan *et al.*, 2021a; Sani *et al.*, 2023; Islam,

2025; Islam *et al.*, 2025b; Hasan *et al.*, 2025). The continuous, low-level exposure of consumers to these residues through the food chain poses risks of allergic reactions, direct organ toxicity, and disruption of the human gut microbiome, which plays a vital role in health and immunity (Hossain *et al.*, 2025).

Table 1 summarizes published studies from Bangladesh (2013–2025) reporting antibiotic misuse in poultry, patterns of AMR, and the detection of resistance genes, highlighting widespread indiscriminate use, multidrug resistance, residue accumulation in poultry products, and associated public health risks.

Table 1. Summary of studies on antibiotic misuse, antimicrobial resistance, and associated public health risks in poultry production in Bangladesh (n=43).

Year	Name of antibiotic misuse	Key findings	Reference
2025	Ciprofloxacin	Uncontrolled ciprofloxacin use leads to substantial residue accumulation in broiler tissues and alters key hematological indicators, underscoring the need for strict adherence to withdrawal periods to protect public health.	Hasan <i>et al.</i> (2025b)
2025	Fluoroquinolones, Penicillin, Aminoglycoside, Macrolides, Nitroimidazoles, Lincosamides, Cephalosporins, Pleuromutilins, Amphenicols, Polymixins, Tetracyclines, Sulfonamides	Widespread and often indiscriminate antimicrobial use in Bangladeshi poultry farms poses significant risks of drug residues and resistance, highlighting the urgent need for farmer education and proper antimicrobial management.	Hasan <i>et al.</i> (2025a)
2025	Amoxicillin	Long-term exposure to amoxicillin residues in mice leads to tissue accumulation, liver and kidney damage, immune suppression, and altered weight gain, emphasizing the need for controlled antibiotic use to prevent health hazards.	Islam <i>et al.</i> (2025a)
2025	Multidrug	Most chicken farmers in southwestern Bangladesh use antibiotics indiscriminately—primarily for disease prevention and often through water—with limited awareness of potential human health risks, highlighting the urgent need for farmer education and awareness programs.	Islam <i>et al.</i> (2025b)
2024	Heavy metals	widespread lack of stakeholder awareness on heavy metal contamination in poultry feeds in Sherpur, Bangladesh, identifies elevated cadmium and chromium levels exceeding safety limits, and highlights the need for regulatory oversight and improved feed formulation to ensure poultry health and food safety.	Islam <i>et al.</i> (2024a)
2024	Cefalexin	Chronic exposure to cefalexin residues above the MRL in mice leads to tissue accumulation, liver and kidney damage, immune suppression, and altered body weight, highlighting the need to prohibit such high-residue antibiotics in the food chain.	Islam <i>et al.</i> (2024b)
2024	Amoxicillin	Judicious use of amoxicillin in poultry is safe and does not affect hematological parameters, but widespread misuse in Bangladesh underscores the urgent need for monitoring, education, and regulation to prevent antibiotic residues and associated public health risks.	Islam and Islam (2024)
2023	Amoxicillin, Ciprofloxacin, Cefalexin, Enrofloxacin, Oxytetracycline	While farmers in Bangladesh are generally aware of the health risks of antibiotic residues, indiscriminate use—without observing withdrawal periods—leads to detectable residues in broiler tissues, emphasizing the importance of both education and proper withdrawal for safe meat production.	Islam <i>et al.</i> (2023)
2023	Multidrug	The knowledge of informal prescribers in the Mymensingh division strongly influences their attitudes and practices regarding antibiotic use, residues, and resistance, while sociodemographic factors such as age and district also play a significant role.	Sani <i>et al.</i> (2023)

Table 1. Contd.

Year	Name of antibiotic misuse	Key findings	Reference
2023	Amoxicillin, Chlortetracycline, Colistin, Ciprofloxacin, Doxycycline, Enrofloxacin, Erythromycin, Sulfaquinolone, Cefalexin, Oxytetracycline, Trimethoprim, Gentamicin, Sulfadiazine, Neomycin, Acetazolamide, Pefloxacin	In Bangladeshi poultry farms, widespread misuse of antibiotics and lack of awareness about AMR underscore the critical need for veterinarian supervision and farmer education to ensure responsible antimicrobial use.	Tasmim <i>et al.</i> (2023)
2022	Doxycycline, Oxytetracycline, Ciprofloxacin, Levofloxacin, Enrofloxacin, Erythromycin, Azithromycin, Tylosin, Neomycin, Amoxicillin, Colistin	Antibiotic use is widespread in Bangladeshi commercial chicken farms, driven by illness, veterinary advice, and prophylactic practices, highlighting the need for improved farming practices and stakeholder education to reduce misuse and mitigate AMR.	Chowdhury <i>et al.</i> (2022)
2022	Levofloxacin, Doxycycline, Cefotaxime, Ciprofloxacin	In Bangladesh, broiler chickens, farmworkers, and farm sewage harbored high levels of multidrug-resistant <i>E. coli</i> , driven by poor biosecurity and unprescribed antibiotic use, highlighting significant risk of antibiotic-resistant transmission in poultry farms.	Mandal <i>et al.</i> (2022)
2021	Ciprofloxacin	Improper ciprofloxacin use in broilers leads to detectable tissue residues and significant hematological alterations, underscoring the health risks associated with antibiotic misuse.	Anaruzzaman <i>et al.</i> (2021)
2021	Enrofloxacin	Enrofloxacin misuse and failure to observe withdrawal periods significantly increase residue deposition in broiler tissues and influence growth performance, underscoring ongoing antibiotic abuse in poultry production.	Bhuiyan <i>et al.</i> (2021a)
2021	Enrofloxacin	neither discriminate nor indiscriminate enrofloxacin use produced significant hematological alterations in broilers, suggesting minimal impact of residual antibiotics on key blood parameters.	Bhuiyan <i>et al.</i> (2021b)
2021	Colistin	Colistin misuse significantly alters key hematological parameters in broilers, emphasizing the need to better understand and regulate antibiotic impacts in poultry production in Bangladesh.	Hasan <i>et al.</i> (2021a)
2021	Colistin	Improper colistin use leads to substantial residue deposition in broiler tissues and significantly increases growth performance, highlighting critical food safety risks associated with antibiotic abuse in Bangladesh.	Hasan <i>et al.</i> (2021b)
2021	Cephalexin	Indiscriminate cephalexin use leads to significant residue accumulation in broiler tissues and alters key hematological parameters, highlighting the risks posed by failure to follow withdrawal periods.	Hossain <i>et al.</i> (2021)
2021	Amoxicillin, Ciprofloxacin, Cephalexin, Enrofloxacin, Oxytetracycline, Gentamicin, Neomycin	Poultry products from the Dinajpur district of Bangladesh are largely free of antibiotic residues, though proper withdrawal periods remain essential to ensure food safety.	Islam <i>et al.</i> (2021)
2021	Colistin sulfate	Both discriminate and indiscriminate use of colistin sulfate in broilers for two weeks had no significant effect on body weight or hematological parameters, indicating short-term use may not alter these physiological measures, though further research is needed for confirmation.	Trisha <i>et al.</i> (2021)

Table 1. Contd.

Year	Name of antibiotic misuse	Key findings	Reference
2021	Multidrug	In commercial poultry production in Bangladesh, both small- and large-scale farmers rely heavily on dealers, company veterinarians, and sales representatives for antibiotics, often using them indiscriminately without proper diagnosis, highlighting the need for policy reforms and improved regulation to curb AMR.	Hasan <i>et al.</i> (2021c)
2021	Multidrug	In Bangladesh, widespread and unregulated antibiotic use in commercial chicken and aquaculture industries has led to multidrug-resistant bacteria, highlighting the urgent need for farmer education, improved veterinary practices, and government-led One Health policies to mitigate AMR.	Chowdhury <i>et al.</i> (2021)
2021	Tetracycline, Ciprofloxacin, Enrofloxacin, Erythromycin, Tylosin, Colistin Sulfate	A study in Bangladesh found high colonization of ESBL-producing <i>E. coli</i> in humans, poultry, and wastewater, with shared resistance genes across sources, but human colonization was not significantly linked to poultry exposure, highlighting bidirectional transmission of antibiotic resistance between humans, animals, and the environment and the need for One Health mitigation strategies	Rousham <i>et al.</i> (2021)
2020	Tylosin	Tylosin residues accumulate across broiler tissues—most prominently in liver and kidney—and can alter select hematological parameters and early growth, underscoring the importance of adhering to withdrawal periods to minimize residual contamination.	Das <i>et al.</i> (2020b)
2020	Doxycycline	Failure to follow doxycycline withdrawal periods results in significant residue deposition across broiler tissues, highlighting the ongoing problem of antibiotic misuse in Bangladesh.	Ali <i>et al.</i> (2020)
2020	Ciprofloxacin, Doxycycline, Tylosin, Oxytetracycline, Enrofloxacin, Erythromycin, Colistin Sulfate	In Bangladesh's small-scale broiler sector, poultry dealers strongly influence farmers' antibiotic use through credit-based, patron-client relationships, suggesting that interventions to promote responsible antibiotic use should target dealers, feed suppliers, and pharmaceutical actors within the production network.	Masud <i>et al.</i> (2020)
2020	Multidrug	A survey of 70 commercial poultry farmers in Bangladesh revealed widespread misuse of antibiotics—driven largely by lack of veterinary guidance—with most farmers unaware of AMR, highlighting the urgent need for education and supervision to ensure prudent antibiotic use.	Tasmim <i>et al.</i> (2020)
2020	Ciprofloxacin, Amoxicillin, Tiamulin, Colistin, Doxycycline, Neomycin	A survey of 140 commercial poultry farms in Chattogram, Bangladesh, found that nearly all farmers used antimicrobials—mostly prophylactically—with common drugs varying by production type, highlighting the need for record-keeping and antimicrobial stewardship to ensure appropriate and effective usage.	Imam <i>et al.</i> (2020)
2020	Colistin	A study in Bangladesh found high levels of colistin-resistant bacteria in poultry and native chickens, with 61.7% of isolates showing phenotypic resistance and <i>mcr</i> -genes (mainly <i>mcr</i> -1 and <i>mcr</i> -2) significantly associated with resistance, particularly in poultry gut bacteria, and prior colistin use strongly increasing both resistance and <i>mcr</i> -gene prevalence.	Islam <i>et al.</i> (2020)
2020	Colistin	A study of broiler chickens in Bangladesh found that 25% of commensal <i>E. coli</i> carried the <i>mcr</i> -1 gene, with genetically diverse strains harboring multiple AMR genes, indicating widespread horizontal transfer of colistin resistance rather than clonal expansion, and colistin use in flocks was positively associated with <i>mcr</i> -1 prevalence.	Ahmed <i>et al.</i> (2020)

Table 1. Contd.

Year	Name of antibiotic misuse	Key findings	Reference
2020	Ampicillin, Tetracycline, Chloramphenicol, Erythromycin, Enrofloxacin, Norfloxacin, Ciprofloxacin, Streptomycin, Colistin, Gentamicin	A study in Bangladeshi layer farms found that <i>E. coli</i> isolates carrying APEC-associated virulence genes were present in organs, feces, and air, with all isolates being multidrug-resistant—showing 100% resistance to ampicillin and tetracycline—and highlighting their potential public health impact.	Ievy <i>et al.</i> (2020)
2020	Oxytetracycline, Ciprofloxacin	A study of commensal <i>E. coli</i> from broiler chickens and farm environments in Bangladesh revealed high resistance levels, with all isolates resistant to oxytetracycline and 78.4% resistant to ciprofloxacin, and widespread presence of <i>tetA</i> , <i>tetB</i> , and <i>tetC</i> genes, indicating a serious risk of transmitting drug-resistant bacteria to humans via the food chain.	Das <i>et al.</i> (2020a)
2020	Amoxicillin, Streptomycin, Tetracycline, Ciprofloxacin, Amoxicillin, Norfloxacin, Azithromycin	A study of broiler farms in Bangladesh found <i>Campylobacter</i> in 26.4% of samples, with higher contamination in conventional farms (36.4%) than in good practice farms (16.5%); among isolates, 67.7% were <i>C. jejuni</i> and 32.3% <i>C. coli</i> , and around one-third were multidrug-resistant, highlighting a significant food safety and public health risk.	Alam <i>et al.</i> (2020a)
2020	Tetracycline, Amoxicillin, Streptomycin, Fluoroquinolones, Macrolides	A study in Bangladesh found 32% of poultry farm and live bird market samples contaminated with <i>Campylobacter</i> spp., with 49% of <i>C. jejuni</i> and 42% of <i>C. coli</i> strains being multidrug-resistant; antimicrobial residues were also frequently detected in meat and liver, and poor hygiene, indiscriminate antimicrobial use, and inadequate waste management were key risk factors, highlighting urgent One Health interventions.	Neogi <i>et al.</i> (2020)
2020	Tetracycline, Chloramphenicol, Ampicillin, Streptomycin	A study in Bangladesh detected multidrug-resistant <i>Salmonella enterica</i> Typhimurium in broiler chickens, with high resistance to tetracycline, chloramphenicol, ampicillin, and streptomycin, carrying resistance genes <i>tetA</i> , <i>floR</i> , <i>bla</i> _{TEM-1} , <i>aadA1</i> , and class 1 integron (<i>int1</i>), highlighting a significant zoonotic and food safety risk	Alam <i>et al.</i> (2020b)
2019	Amoxicillin	Neither discriminate nor indiscriminate amoxicillin use produced meaningful alterations in broiler hematological parameters, indicating minimal impact of residual antibiotics on key blood indices.	Islam <i>et al.</i> (2019a)
2019	Amoxicillin	Amoxicillin residues persist in broiler tissues, with the highest levels observed in indiscriminate use, highlighting the risks of antibiotic misuse for human health.	Islam <i>et al.</i> (2019b)
2019	Enrofloxacin, Ciprofloxacin, Amoxicillin	Broiler sellers in Mymensingh have limited awareness of antibiotic misuse, while enrofloxacin, ciprofloxacin, and amoxicillin residues were commonly detected in broiler liver and meat, highlighting the need for community-based education and monitoring to reduce antibiotic residues and AMR.	Khan <i>et al.</i> (2019)
2019	Ciprofloxacin, Enrofloxacin, Amoxicillin, Oxytetracycline, Sulfa Drugs, Norfloxacin	A survey of 120 small-scale layer farms in Mymensingh, Bangladesh, revealed widespread indiscriminate antibiotic use, poor egg and farm management practices, low awareness of residues and withdrawal periods, and frequent use of critically important human antibiotics, highlighting the need for improved management and education to mitigate AMR.	Ferdous <i>et al.</i> (2019)

Table 1. Contd.

Year	Name of antibiotic misuse	Key findings	Reference
2019	Ampicillin, Tetracycline, Sulfamethoxazole-Trimethoprim, Nalidixic Acid	A study of apparently healthy broilers in Chattogram, Bangladesh, found that 61.7% carried <i>E. coli</i> , all of which were multidrug-resistant and harbored <i>bla</i> _{TEM} , <i>tetA</i> , and <i>Sul2</i> genes, indicating a significant potential public health risk.	Sarker <i>et al.</i> (2019)
2019	Ampicillin, Tetracycline, Streptomycin, Ciprofloxacin, Erythromycin, Trimethoprim–Sulfamethoxazole, Colistin Sulfate, Gentamicin	A study in Bangladesh found that <i>E. coli</i> from broiler chickens were universally resistant to multiple antibiotics—including ampicillin, tetracycline, streptomycin, ciprofloxacin, erythromycin, and trimethoprim-sulphamethoxazole—with high prevalence of resistance genes (<i>tet(A/B)</i> , <i>bla</i> _{TEM} , <i>aadA1</i> , <i>ere(A)</i> , <i>dfrA1</i>), highlighting widespread multidrug resistance and the urgent need for surveillance to guide antimicrobial use.	Azad <i>et al.</i> (2019)
2016	Colistin, Trimethoprim, Doxycycline, Ciprofloxacin, Enrofloxacin, Tylosin, Amoxicilin, Sulfamethoxazole, Oxytetracycline, Erythromycin, Sulfachloropyridazine, Sulfadiazine, Neomycin, Norfloxacin, Pefloxacin, Flumequine, Ampicillin, Azithromycin, Cephalosporin	A survey of 73 broiler farms in Bangladesh revealed widespread multi-drug antibiotic use—mostly for therapy and prophylaxis—with over 60% of farmers using antibiotics without prescription and 26% of meat samples containing residues, highlighting a significant public health risk and the need for prudent antibiotic use strategies.	Islam <i>et al.</i> (2016)
2013	Multidrug	A study in rural Bangladesh revealed that close human–livestock interactions, shared housing and water, and reliance on unlicensed village doctors for both human and animal healthcare—including frequent antimicrobial use—may increase the risk of antimicrobial-resistant pathogen transmission.	Roess <i>et al.</i> (2013)

3.4. Technological and management innovations

The environmental and ethical impacts of broiler production in Bangladesh are increasingly concerning. Each broiler bird produces about 1.5–2.0 kg of litter per production cycle, and with over 200 million birds produced annually, the industry generates millions of tons of waste. This litter is often dumped openly or applied directly to crop fields without treatment. Raw application leads to high nutrient runoff, contaminating groundwater with nitrates and causing eutrophication in rivers and ponds. Additionally, decomposing litter releases ammonia and greenhouse gases like methane and nitrous oxide, which have high global warming potential (Zhang *et al.*, 2023). Animal welfare is also a major concern. Intensive breeding for rapid growth and high breast meat yield has made broilers prone to metabolic disorders, such as ascites and sudden death syndrome. High stocking densities, often exceeding 30 kg/m², and poor ventilation exacerbate health problems, resulting in footpad dermatitis, hock burns, and chronic heat stress. These conditions cause pain, reduce productivity, and negatively affect meat quality, highlighting the urgent need for improved management practices that balance ethical concerns with industry sustainability (Riber and Wurtz, 2024).

3.5. Advanced biosecurity and vaccination innovations

A wide array of technologies and management practices holds the key to breaking the cycle of disease, drug dependence, and environmental degradation. Biosecurity is the first and most cost-effective line of defense against disease. For well-resourced farms, this includes strict measures such as perimeter fencing, controlled access points with mandatory foot baths and vehicle dips, provision of dedicated farm clothing and footwear, and the rigorous implementation of an "all-in-all-out" production system that allows for thorough cleaning, disinfection, and downtime between flocks (Arif *et al.*, 2021). However, the adoption of these practices among small and medium-scale farmers remains dismally low, primarily due to perceived costs, lack of space, and

limited understanding of their economic benefits (Conan *et al.*, 2024). While conventional vaccines are vital, next-generation technologies offer significant advantages. Recombinant vector vaccines, such as those using the HVT (Herpesvirus of Turkey) platform to deliver protective antigens against ND or AI, can provide longer-lasting and broader immunity with a single administration. Hatchery-based vaccination methods, particularly *in-ovo* vaccination (administered into the egg around day 18 of incubation), ensure 100% coverage of chicks and remove the variability and labor associated with manual vaccination on the farm (Kapczynski *et al.*, 2013). These technologies, currently used mainly by integrated companies, represent the future of efficient and reliable disease prevention.

3.6. Alternatives to antibiotics and sustainable management tools

Probiotics and direct-fed microbials are live microbial supplements that benefit the host by competitively excluding pathogens, modulating the immune system, and improving nutrient digestibility (Kabir, 2025). Global studies show that specific strains of *Bacillus* and *Lactobacillus* can improve feed conversion by 5–8% and reduce mortality, effectively replicating the benefits of antibiotic growth promoters (Mingmongkolchai and Panbangred, 2018).

Phytogenic feed additives, including herbs, spices, and their extracts such as neem (*Azadirachta indica*), turmeric (*Curcuma longa*), and black cumin (*Nigella sativa*), have antimicrobial, antioxidant, anti-inflammatory, and immunostimulatory effects. Dietary supplementation with these botanicals can enhance vaccine responses, growth performance, and gut microbiota composition (Dhama *et al.*, 2015). Organic acids (formic, propionic, lactic acid) and feed enzymes like phytase improve feed efficiency, inhibit pathogenic bacteria, and reduce phosphorus excretion by up to 40%, mitigating environmental pollution (Haque *et al.*, 2021; Adeola and Cowieson, 2024).

Precision livestock farming (PLF) uses sensors, cameras, and microphones to monitor environmental conditions and animal health in real time, allowing early detection of disease or stress (Berckmans, 2014). Although adoption in Bangladesh is limited, PLF has strong potential to improve welfare, resource efficiency, and productivity. Waste valorization through aerobic composting or anaerobic digestion transforms poultry litter into organic fertilizer or biogas, turning waste into a valuable resource while promoting environmental sustainability (Wilkinson, 2011).

4. Pathways to a sustainable and resilient broiler sector

4.1. Deconstructing the interlinked crisis

Our synthesis reveals that the challenges of disease, AMR, and environmental degradation are not discrete problems but are dynamically linked in a self-reinforcing vicious cycle. The endemicity of high-impact diseases like AI and ND creates a pervasive atmosphere of risk and uncertainty among farmers. We interpret this to mean that this risk perception, combined with often inadequate biosecurity, drives the preemptive and metaphylactic use of antibiotics as a form of financial insurance. This massive and often indiscriminate antimicrobial pressure acts as a powerful evolutionary selector, enriching for resistant bacterial populations within the poultry gut and farm environment (Bhuiyan *et al.*, 2021a; Islam and Islam, 2024), which posit that these resistant bacteria, and the mobile genetic elements they carry, can then transfer through various pathways—via contaminated meat, direct contact with birds, or environmental runoff—into human populations, compromising the efficacy of essential medicines (Robinson *et al.*, 2016). Simultaneously, the environmental stressors stemming from poor waste management, such as high ammonia levels, act as immunosuppressants, making birds more susceptible to primary and secondary infections, which in turn perpetuates the perceived need for antimicrobial interventions. Breaking this cycle requires disarming its core components simultaneously; focusing on any single issue in isolation is destined to fail.

4.2. Bridging the chasm between knowledge and action

A key insight from this review is the striking gap between available scientific solutions and their practical adoption, particularly among small and medium-scale farmers who form the backbone of Bangladesh's poultry industry. While policy initiatives such as the ban on antibiotic growth promoters and the National Action Plan on AMR represent important steps, their impact has been limited by weak implementation. Regulatory bodies often lack the capacity to monitor drug sales, inspect farms, or conduct residue surveillance at slaughterhouses, and the persistent over-the-counter availability of critical antibiotics continues to undermine these efforts. Effective policy must therefore move beyond symbolic measures to enforceable compliance, supported by credible monitoring and meaningful penalties (Robinson *et al.*, 2016; Chowdhury *et al.*, 2021).

Economic constraints further hinder adoption. Smallholder farmers operating on narrow margins face a stark trade-off: the immediate cost of investing in probiotics or composting infrastructure versus the abstract and future benefits of reduced AMR risk or improved fertilizer returns. Long-term gains, such as lower mortality or veterinary costs, are often overshadowed by the pressing need to maintain cash flow (Kabir *et al.*, 2023). Addressing this requires demonstrating clear, short-term returns through pilot projects and providing financial support mechanisms, including targeted subsidies, low-interest green loans, or premium pricing for certified sustainable products, to reduce the perceived risk of adopting new practices.

Finally, a persistent knowledge transfer bottleneck limits the spread of promising research on alternatives to antibiotics and waste valorization. Innovations from institutions like BLRI and BAU frequently fail to reach the field, as the public extension system is overstretched and often lacks the technical expertise needed for modern livestock management. Bridging this gap requires innovative solutions, such as digital advisory platforms, strengthened private-sector extension services, and farmer field schools where producers can directly observe the benefits of new technologies, thereby facilitating more rapid and confident adoption (Conan *et al.*, 2024).

4.3. Roadmap for a sustainable broiler industry

4.3.1. Strategic actions for government and regulators

Navigating the transition to a sustainable broiler industry requires coordinated efforts from all stakeholders, starting with government and regulatory bodies. Key actions include moving from policy formulation to enforcement by empowering the drug administration and DLS with legal authority and logistical resources to implement bans on non-therapeutic antibiotic use and penalize illegal sales. Governments should also create smart incentives, such as tax breaks or direct subsidies, to encourage farmers to adopt certified biosecurity measures, waste processing technologies, and antibiotic-free production protocols. Additionally, investing in One Health surveillance is crucial, involving the establishment of an integrated national system that monitors antimicrobial resistance in poultry, humans, and the environment, alongside tracking antibiotic residues in the food chain, with data shared across relevant ministries to inform policy and action (Bristy *et al.*, 2019).

4.3.2. Empowering industry and farmers

For the broiler industry and farmers, transitioning to sustainable practices can be accelerated through collective action and responsible leadership. Encouraging the formation of farmer cooperatives or producer organizations allows members to pool resources for shared technologies, such as centralized composting units or feed mills with enzyme processing, achieve economies of scale in procurement, and strengthen market bargaining power. Simultaneously, large integrated companies must lead by example, committing publicly to transparent antibiotic stewardship, high animal welfare standards, and robust environmental management, thereby setting benchmarks that drive industry-wide adoption of sustainable practices (Masud *et al.*, 2020; Zhu and Wang, 2024).

4.3.3. Driving research and innovation

Researchers and academics play a critical role in supporting a sustainable broiler industry by focusing on context-specific, cost-effective solutions. This includes optimizing the extraction and dosage of indigenous phytochemicals, developing robust probiotic strains adapted to the Bangladeshi climate and feed systems, and designing low-cost, durable precision livestock farming (PLF) sensors (Kabir and Islam, 2021). Additionally, conducting rigorous socio-economic studies to quantify the total cost of ownership and return on investment of sustainable practices provides farmers and policymakers with concrete economic evidence to guide informed decision-making and promote the adoption of sustainable technologies.

4.3.4. Empowering consumers and market incentives

Consumers and retailers are pivotal in driving the shift toward sustainable poultry production by generating demand for responsibly produced products. Nationwide public awareness campaigns can educate consumers about the dangers of AMR and the benefits of safely and sustainably produced poultry, creating a market that rewards responsible practices. Retailers and processors can further reinforce this shift by developing trusted certification and labeling schemes for products such as "reduced antibiotic use" or "sustainably produced" chicken, establishing differentiated markets that provide farmers with economic incentives to adopt sustainable practices (Abreu *et al.*, 2023; Acosta *et al.*, 2025).

4.4. Limitations of the review

This review is limited by the availability and quality of existing literature. Large-scale, long-term studies in Bangladesh are scarce, making it difficult to fully assess the economic, health, and environmental impacts of

sustainable broiler production. There is also a risk of publication bias, as positive results may be reported more often than neutral or negative outcomes. Future research should focus on on-farm intervention trials and detailed life-cycle assessments of sustainable technologies to provide stronger evidence for policy and practical decision-making.

5. Conclusions

The Bangladeshi broiler industry is at a critical crossroads. Its rapid growth is now threatened by unsustainable practices, including excessive antimicrobial use, which drives resistance and endangers public health. Environmental and welfare shortcomings further undermine the sector's sustainability. This review highlights that continuing "business-as-usual" risks crisis, while a shift toward safety and sustainability—through biosecurity, precision health management, alternatives to antibiotics, and circular waste management—is essential. Achieving this requires collaboration, political will, strategic investment, and effective knowledge transfer. Enforceable policies, farmer incentives, and research on long-term benefits of integrated sustainable systems are urgently needed to guide a successful industry transformation.

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Data availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Conflict of interest

None to declare.

Authors' contribution

Md. Shafiqul Islam: Conceptualization of the review, design of the thematic framework, project administration, writing- original draft, writing - critical review & editing, final approval of the manuscript; Md. Mahmudul Hasan: Development of the literature search strategy, data curation, literature collection and sorting, formal analysis and synthesis of the collected data, validation of included studies, visualization (figure/table preparation), review & editing; S. M. Lutful Kabir: formal analysis and synthesis of the collected data, writing - review & editing. All authors have read and approved the final manuscript.

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