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Mitigation of antimicrobial resistance in avian husbandry through the supplementation of *Lactiplantibacillus plantarum* as a probiotic intervention

Own Nasir [1], Muhammad Talha Aziz [2], Ghaleb Oriquat [3], Rana Abdul Rehman [1], Kamel A. Saleh [1], Gul Bahar Bano [4], Ruhma Naveed [4], Robail Saher [4], Maria Batool [4], Nouman Tariq [1*], Arslan Muhammad Ali Khan [1]

[1] *Faculty of Veterinary Science, University of Agriculture Faisalabad, Faisalabad, Pakistan*
[2] *Masters in Public Health, St. Francis College Brooklyn, NY, USA*
[3] *Faculty of Allied Medical Sciences, Hourani Center for Applied Scientific Research, Al-Ahliyya Amman University, Amman, Jordan*
[4] *University Institute of Diet and Nutritional Sciences, Faculty of Allied Health Sciences, The University of Lahore, Lahore, Pakistan*

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* *Corresponding author:*
Nouman Tariq
Email: noumantariq0208@gmail.com

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Abstract

Poultry products, in the form of meat and eggs, are among the most affordable sources of animal protein for humans. The widespread use of sub-therapeutic antibiotics is one of the major causes of antimicrobial resistance (AMR) emergence in poultry. The extensive use of antibiotics exerts selective pressure on the gut microbiota and promotes resistance in pathogenic microbes. To address this threat, researchers are continuously searching for suitable alternatives that inhibit pathogens like *E. coli* and promote production in poultry. *Lactiplantibacillus plantarum*, a probiotic, has gained considerable attention for its ability to maintain gut health, reduce disease risk, and enhance immune response. It can modulate gut microbiota, produce antimicrobial compounds such as bacteriocins, and disrupt signalling processes among pathogens. *L. plantarum*, when used in commercial feed for poultry, can enhance meat quality in broilers and egg production in layers. Despite these potential benefits, further research is needed to determine species-specific dose rates, efficacy, and stability in different field conditions. Modern delivery methods such as microencapsulation can improve its stability and viability. Furthermore, combining it with other feed additives such as phytogenic compounds and prebiotics may further enhance its activity by synergistic interaction. This review highlights the growing threat of antimicrobial resistance in birds and explores the role of *L. plantarum* as a probiotic in improving the health and sustainability of the poultry industry.

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1. Introduction

In recent years, poultry production has become an important source of animal-derived protein because of its low input costs, easy availability, short generation interval, and high feed conversion ratio, which potentially ensures global food security (Tariq et al. 2025; Ramzan et al. 2025). Poultry producers have increasingly adopted industrial-scale practices, including uniform genetic and breeding lines, intensive confinement in enclosed rearing systems, and controlled artificial lighting to enhance productivity (Shang et al. 2024; Ashaolu et al. 2025). Despite their benefits, such intensive production practices create an ideal environment for pathogen transmission and disease outbreaks, particularly under the conditions of wet litter and poor ventilation in poultry sheds (Laban et al. 2025; Sarfraz et al. 2025). To control bacterial infection and boost the growth performance, producers have excessively used sub-therapeutic levels of antibiotics. This approach proved effective in treating common poultry diseases such as colibacillosis, caused by *Escherichia coli* (*E. coli*), and necrotic enteritis, caused by *Clostridium perfringens* (Naeem and Bourassa 2025; Slick et al. 2025). However, excessive and prolonged use of such antibiotics disrupt the composition of the gut microbiota, normally present in the GIT of birds.

Pathogens, such as *E. coli* and *Klebsiella pneumoniae*, may rapidly develop resistance to sub-therapeutic antibiotic doses through mutation, acquirement, or expression of resistance genes (Abreu et al. 2023; Dongre et al. 2025). These genes enable bacteria to evade antibiotics and spread rapidly, making antimicrobial resistance a critical threat to the poultry industry (Tariq et al. 2025; Arshad et al. 2025). Due to the growing threat of AMR, global health agencies, including the World Health Organization (WHO), have called for prudent use of antimicrobials in both livestock and poultry farming (Ishaque et al. 2025; Naheed et al. 2025). These concerns have prompted researchers and producers to explore viable alternatives, including organic acids, phytobiotics, probiotics, prebiotics, synbiotics, bacteriophages, enzymes, antimicrobial peptides, and hyper-immune egg antibodies (Hussain 2025; Phupaboon et al. 2025; Siddiqui et al. 2025; Sweidan et al. 2025; Ullah et al. 2025). Among these alternatives, probiotics have gained substantial importance because of their better results in poultry and livestock (Mateen et al. 2025).

Probiotics are live microorganisms that are naturally present in the GIT of birds, and when they are used as feed additives, provide significant health benefits by improving the gut's microbial balance and improving the growth of intestinal villi (Acharya and Barsila 2025; Anaya et al. 2025; Haryati et al. 2025). Probiotic supplementation modulates the gut microbial microenvironment, suppresses pathogen proliferation, and produces the beneficial metabolites, including butyrate and other short chain fatty acids, which support enterocytes and enhance mucosal barrier integrity (Ayesiga et al. 2024). Among

probiotics, *L. plantarum* has shown promising results due to its remarkable probiotic abilities in birds. *L. plantarum* is a heterofermentative lactic acid-producing with significant adaptability and widespread use in food fermentation (Zhao et al. 2025). Earlier, it was included in the genus *Lactobacillus*; however, it has been reclassified into the genus *Lactiplantibacillus* and family Lactobacillaceae (Bu et al. 2023). It is a Gram-positive, rod-shaped, non-spore-forming, non-motile bacterium that usually occurs in single, pair, or chain forms (Zhang et al. 2024; Garcillán-Barcia et al. 2025). It has broad-spectrum immunomodulatory and antimicrobial properties (Chatsirisakul et al. 2025). *L. plantarum* can survive in diverse habitats such as fermented silage, savoury food products, and the gastrointestinal tract of poultry (Wang et al. 2024). It has the ability to survive in acidic conditions, even up to pH 3 or lower; it can evade digestive enzymes like pepsin and tolerate bile salts. In the GIT, it may competes with pathogens for adhesion and nutrients. This competitive exclusion limits the proliferation of pathogens due to a the limited access to nutrient and space for colonization and growth (Rocchetti et al. 2021).

Supplementation of *L. plantarum* strains with feed may improve feed conversion ratio and weight gain of birds compared to other probiotics present in commercial feed for poultry (Chang et al. 2022). It may also improves the digestive functions of laying birds by enhancing nutrient utilization and maintaining gut microbiota (Zhang et al. 2023a). Although some strains of *L. plantarum* have shown excellent safety profile with respect to the transfer of resistance and virulence determinants, strain-specific genomic and phenotypic safety evaluations is warranted for declaring them safe as probiotics in poultry (Shi et al. 2024). Although it is a versatile probiotic, researchers still face distinct physiological, operational, and clinical hurdles. Its probiotic activity depends upon many factors, including proper dosage, strain specificity, and maintenance of conditions like temperature and humidity. Researchers are trying to adjust dose requirements for different species and strains (Aljohani et al. 2024). Further improvements in delivery methods such as microencapsulation and combination with other additives, including prebiotics or phytogenic compounds, can further improve its efficacy. This review discusses the mechanisms of antimicrobial resistance, the probiotic properties of *L. plantarum,* its mode of action, and its potential application in poultry nutrition, with emphasis on current challenges and future aspects.

2. Review methodology

Literature was searched from electronic databases – PubMed, Scopus, Web of Science, and Google Scholar for the identification of antimicrobial resistance in poultry. The data on probiotic potential of "*Lactiplantibacillus plantarum*" was also checked. The relevant keywords used were *L. plantarum* AND Antimicrobial resistance AND Poultry AND Probiotics AND Gut microbiota AND Growth performance AND Antibiotic alternatives. Original research and review articles that addressed AMR mechanism, probiotic strains and their properties, poultry disease, immune responses and poultry production performance were considered. Irrelevant, duplicate, and unsupported papers were excluded. Relevant articles were checked by title, abstract, full-text availability, and methodology section with their results and discussion for original articles. The findings were synthesized narratively and organized into thematic sections that covered AMR mechanism, probiotic applications, delivery systems, challenges and future directions.

3. Mechanisms of the development of antimicrobial resistance

Bacteria develop antimicrobial resistance in many ways, including enzymatic degradation of antimicrobials, reduced membrane permeability, target site modifications, efflux pump mechanisms, and horizontal gene transfer (Elshobary et al. 2025; Ovchinnikov et al. 2025).

3.1 Limiting drug accumulation and antibiotic inactivation

Bacteria can reduce intracellular drug concentration by adopting mechanisms that prevent the drug from reaching its targets. This is primarily achieved through active efflux pump mechanisms and reduced cell membrane permeability (Elshobary et al. 2025). In the efflux pump mechanism, bacteria have developed protein complexes that actively expel antibiotics from bacterial cells, keeping intracellular drug concentration lower than required for suppression of bacterial growth. *Campylobacter jejuni*, a common GIT pathogen of poultry GIT, overexpresses the CmeABC efflux pump, which expels fluoroquinolones (Cheema et al. 2024; Dai et al. 2024). Upon antibiotic exposure, *E. coli* has been found to downregulate porin proteins such as OmpF and OmpC, which reduce permeability to β-lactams (Batool et al. 2025). One of the most important strategies bacteria use to resist antibiotics is chemical inactivation through specific enzymes that modify or degrade the drug, rendering it ineffective (Zhang and Cheng 2022). In enzymatic degradation, bacteria rapidly produce enzymes that degrade antibiotics; for example, *Salmonella enterica* uses the TEM-type β-lactamase and cephamycinase-2 (an AmpC-type β-lactamase) to neutralize the effect of ampicillin (Diarra et al. 2014; Siddique et al. 2021; Sharma and Kim 2024).

3.2 Target modification and genetic adaptation

To evade antibiotics, bacteria may alter the molecular targets of drugs or acquire resistance genes from an external source. These modifications prevent effective binding of antibiotics to targets, whereas acquired resistance factors can get disseminated rapidly across the bacterial population via horizontal gene transfer (Sher et al. 2025). In target site modulation, bacteria alter the antibiotic binding sites; for example, methylation of 23S rRNA in the 50S ribosomal subunit of *Staphylococcus aureus* results in the development of macrolide (erythromycin) resistance (Yang et al. 2025). During horizontal gene transfer, bacteria transfer resistance genes to neighbours via conjugation, transformation, and transduction (Cinthi et al. 2025). *Enterococcus faecium* transfers the vancomycin resistance gene to Gram-positive bacteria via a plasmid, as shown in Fig. 1 (Sobkowiak et al. 2025).

4. Probiotic characteristics of *L. plantarum*

The probiotic potential of *L. plantarum* comes from its remarkable ability to withstand a harsh gastrointestinal environment, establish itself within the host, and significantly improve gut health and productivity. Its cell wall contains many compounds, including a thick peptidoglycan layer, teichoic acid, and lipoteichoic acid, which maintain cell wall integrity, improve adhesion to the gut epithelium, and enhance the immune response in birds (Li et al. 2024). *L. plantarum* can also produce extracellular polymeric substances (EPS), which form a hydrated matrix around bacterial cells. This matrix acts as a hydrated protective barrier around bacterial cell by retaining water, which strengthens the cell's ability to withstand the harsh gastrointestinal environment. Furthermore, its adhesive properties promote interactions

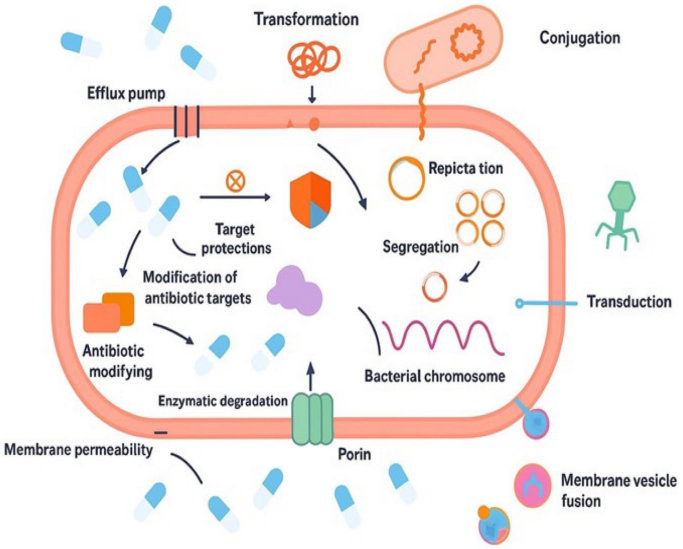


Fig. 1. *Major mechanisms of developing antimicrobial resistance in bacterial pathogens*

with intestinal mucus and epithelial surfaces, thereby enhancing bacterial attachment and persistence (Wu et al. 2022; Shi et al. 2026).

5. Mechanism of Action

L. plantarum may protect the host from pathogens through multiple mechanisms, such as lowering of gut pH, competitive exclusion, disrupting communication between pathogens, production of secondary antimicrobial metabolites, and enhancing the host immune system (Yilmaz et al. 2022; Shi et al. 2024).

5.1 Microbial competition and antimicrobial action

L. plantarum enhances the growth performance in poultry by inhibiting the growth of harmful microorganisms by competing with them for nutrients and space and producing antimicrobial metabolites (Rocchetti et al. 2021). Through competitive exclusion, it establishes itself in the gut by adhering firmly to the intestinal lining and blocking the attachment of several harmful pathogens such as *C. perfringens* (Lu et al. 2025a). At the same time, it deprives pathogens of nutrient uptake by absorbing nutrients essential for pathogenic growth. Furthermore, it produces compounds such as lactic acid, acetic acid, hydrogen peroxide, and bacteriocins like plantarcins. These substances limit the growth of harmful pathogens by directly damaging their plasma membrane and lowering the pH of the gut, which is not suitable for pathogens (Touati et al. 2025). Certain strains of *L. plantarum* have been reported to enhance the activity of sub-therapeutic antibiotic levels (Hao et al. 2024).

5.2 Quorum sensing disruption

Quorum sensing is a bacterial communication system in which bacteria sense their population density through small signalling molecules called autoinducers (AIs) (Zhang et al. 2023b). *L. plantarum* disrupts this process by releasing active metabolites like biosurfactants and octanoic acid, which block the signalling pathways of the pathogen. Octanoic acid inhibits LuxS-mediated autoinducer-2 (AI-2) signalling in pathogens, while biosurfactants interfere with the acyl-homoserine lactone (AHL) circuit, down-regulating key infectious factors such as proteases and pyocyanins. It may interfere with their quorum sensing process by blocking quorum sensing (QS) gene expression either by degrading or inactivating AIs (D'Aquila et al. 2024; Wang et al. 2025a). *L. plantarum* interferes with the agr quorum-sensing of *S. aureus*, resulting in the reduced expression of several virulence factor, such as toxins, extracellular enzymes, and other molecules required for efficient colonization and tissue damage (Sharma and Kim 2024; Li et al. 2025).

5.3 Boosting immunity and strengthening the gut

L. plantarum boosts the host immune system by modulating immune responses and improves the integrity of intestinal barriers. It stimulates the immune response and increases the production of secretory immunoglobulin A (sIgA) in the gut, which neutralizes bacteria and their toxins before they penetrate the intestinal lining (Chen et al. 2025). It may regulate the inflammatory reactions in the gut by balancing pro-inflammatory and anti-inflammatory immune signals, such as increasing anti-inflammatory cytokines like interleukin-10 (IL-10) and inhibiting pro-inflammatory ones like tumor necrosis factor alpha (TNF-α) (Popova-Krumova et al. 2024). It also promotes regulatory T-cell activity, which maintains the body's immune tolerance mechanism and avoids unnecessary autoimmune responses. At the same time, it reinforces the gut lining by attaching to the intestinal lining, facilitating production of mucin and enhancing the expression of tight junction proteins, such as claudins, occludin, and zonula occludens-1 (ZO-1). This reduces gut permeability and prevents harmful microbes and their toxins from leaking into the bloodstream (Du et al. 2024). It also produces acids like lactic acid and some natural antimicrobial substances like bacteriocins that deprive harmful bacteria of nutrients and space by lowering gut pH. Furthermore, it ferments dietary fibers and generates short-chain fatty acids (SCFAs) like butyrate, which reduce local inflammation in colon cells (enterocytes) and strengthen the barrier.

5.4 Microbiota stabilization and nutrient optimization

L. plantarum enhances poultry health by stabilizing and maintaining the gut microbiota. It promotes the growth of beneficial bacteria and suppresses harmful microbes (Lu et al. 2025a). It also boosts fermentation, increasing the production of short-chain fatty acids (SCFAs) such as butyrate. These SCFAs not only provide energy to enterocytes but also exert anti-inflammatory and trophic effects (Katu et al. 2025). Other than the antimicrobial effects, *L. plantarum* may improve the nutrient metabolism and utilization through the production of secondary metabolites and modulating gut microbial activity. It produces enzymes such as alpha-amylase and glycosidases, which break down complex dietary starches and carbohydrates into simple, easily absorbable sugars. Other enzymes, including feruloyl esterases and phytases, break down phytates, making iron, calcium, zinc, and other nutrients readily available for the host to utilize. It may also influence the production of bile and its metabolic byproducts required for the digestion and absorption of macronutrients, including fat, protein, and carbohydrates (Fig. 2). Because of these benefits, it has a potential to become a practical and sustainable solution for modern poultry (Ismael et al. 2024).

6. Applications of *L. plantarum*

In broiler chickens, dietary supplementation of *L. plantarum* is considered effective in modulating gut microbiota, promoting growth performance, improving intestinal health, increasing nutrient utilization, strengthening the immune system, and enhancing meat quality (Ismael et al. 2024). In layer production, it may contribute to disease prevention, egg production and quality, and shell and albumen quality (Li et al. 2026).

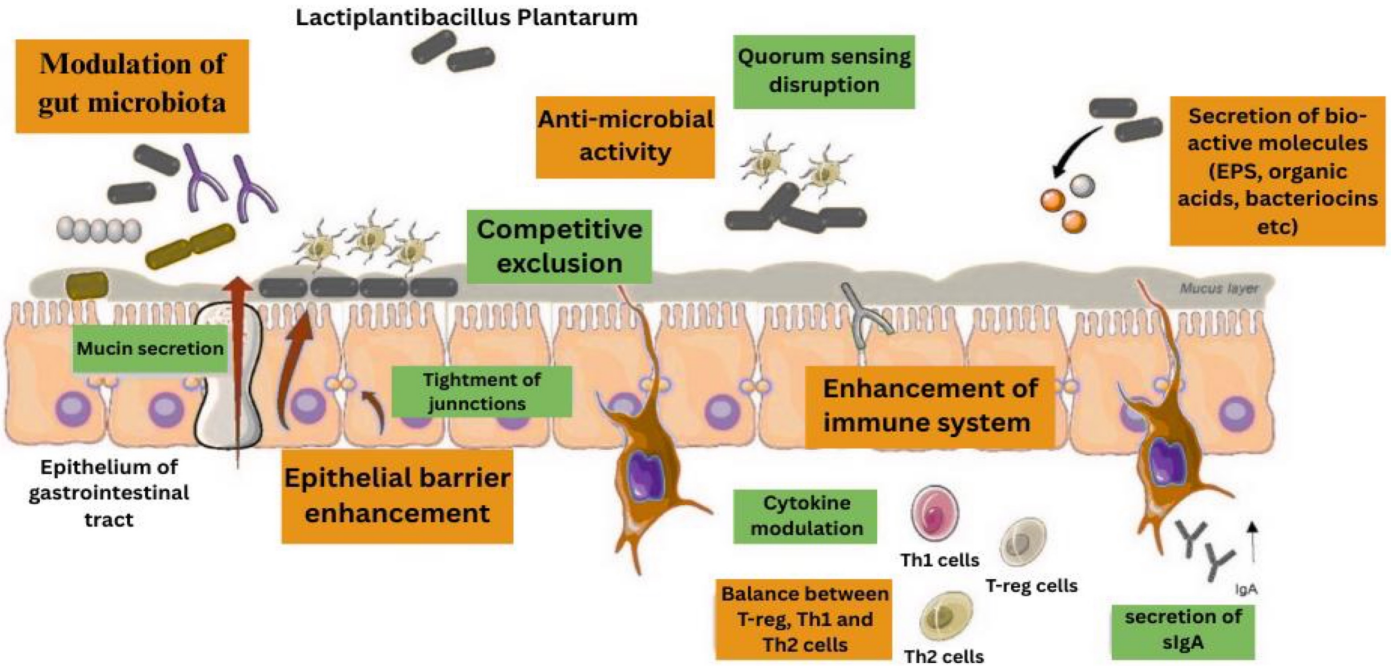


Fig. 2. Proposed mechanisms of action of Lactiplantibacillus plantarum in inhibition of pathogens, modulation of gut microbiota, and host immunity enhancement in poultry

6.1 Gut health and growth performance

The gastrointestinal tract of broiler chickens plays an essential role in digestion and nutrient absorption. Supplementation of *L. plantarum* in the diet improve gastrointestinal activity by establishing a protective microbial barrier that suppresses harmful pathogens like *E. coli* and promotes beneficial microbiota (Wu et al. 2025; Zhong et al. 2025). This improved microbial growth strengthens the mucosal barrier, reduces pathogen-induced inflammation, and enhances enzyme activity for better nutrient utilization (Jiao et al. 2025). All these factors collectively improve growth performance and metabolic efficiency. Earlier studies have reported that broiler chickens revealed an increase in average daily weight gain up to 3.27%, a reduction in feed conversion ratio by 4.55%, an enhancement of feed intake, and better nutrient utilization (Łaszkiewicz et al. 2021; Liu et al. 2023; Liu et al. 2025; Sultana et al. 2025).

6.2 Better meat quality and production

Supplementation of poultry diets with *L. plantarum* enhances the hygienic attributes and quality parameters of poultry meat, thereby potentially increasing the commercial value of poultry products (Woldemariam et al. 2024). Broiler chicken meat from probiotic-fed flocks tends to be more tender, juicier, and palatable than non-probiotic-fed flocks (Liu et al. 2025). *L. plantarum* may function as a potent antioxidant by suppressing lipid peroxidation, which in turn prevents flavour loss, textural deterioration, and rancidity (Wang et al. 2025c). Furthermore, the ability of *L. plantarum* to strengthen muscle biochemistry improves the nutritional profile of poultry meat, as the latest studies show an increase in breast muscle yield from 29.27% to 40.89%, which meets the demand of the commercial market (Li et al. 2025; Liu et al. 2025), as shown in Fig. 3.

6.3 Egg production and quality

In laying hens, supplementation of *L. plantarum* strains in layer diets may exert significant and multifaceted impact on their reproductive performance. It facilitates the digestion and assimilation of essential nutrients, including protein and fat, allowing the host to utilize a greater proportion of metabolic resources for reproduction (Mangan et al. 2025). It has been reported that egg-laying rate increased by 7.90% with enhanced egg quality in birds supplemented with *L. plantarum* strains, which generally has higher consumer acceptance and market value (Zhang et al. 2023a; Gao et al. 2025). It potentially improves egg shell structure by promoting protein stabilization and improving mineral absorption, such as phosphorus and calcium, in the host. These effects results in eggs with greater shell density, thickness, and mechanical strength (Ismael et al. 2024). It may also improve the biochemical characteristics of albumen, which helps maintain freshness and internal egg quality (Zhang et al. 2023a). This combined increase in

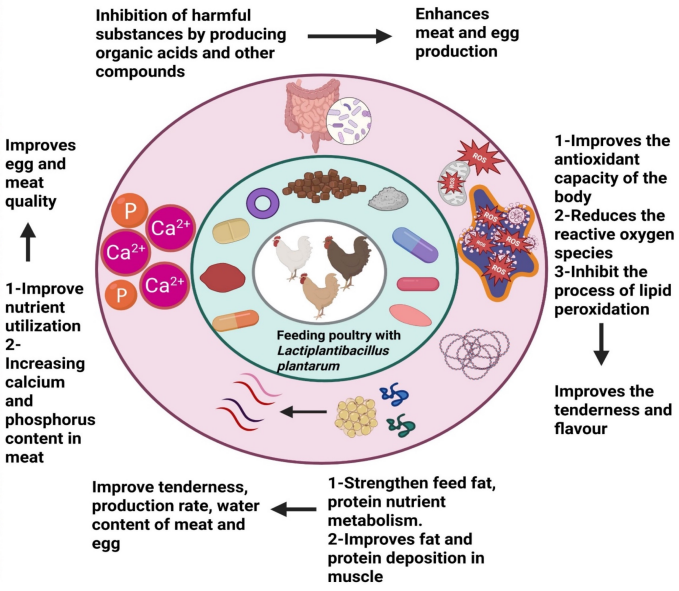


Fig. 3. Application of *Lactiplantibacillus plantarum* in poultry

shell durability and albumen integrity ultimately improves egg quality and can also enhance its commercial value (Chai and Chen 2025). The nutritional benefits and applications of feeding poultry with *L. plantarum* are shown in Fig. 3.

7. Challenges and future prospects

L. plantarum is characterized by its natural origin and continuous use across fermentation-driven substrates but its strain-specific probiotic safety in poultry has not been established yet (Xia et al. 2025). Certain strains maintains intestinal homeostasis by sustaining microbial equilibrium rather than inducing dysbiosis (Bijaoui and Zimmerman 2025; Arif et al. 2025). However, despite these benefits and advanced applications, the use of *L. plantarum* is still limited because of several challenges. One main challenges is the high strain specificity of probiotic properties such as adhesion, antimicrobial activity, immunomodulation, gastrointestinal tolerance, and interaction with existing gut microbiome, which cannot be estimated and generalized for all *L. plantarum* strains. Another major challenge is the potential horizontal transmission of resistance gene by the probiotic strains, which warrants a comprehensive genomic and phenotypic screening before commercialization as a probiotic (Taha et al. 2025). Furthermore, feed composition, storage conditions, pathogen pressure, tempering

Table 1. The functional properties, proposed mechanisms, and potential effects of *L. plantarum* in poultry

Functional activity	Mechanism of action	Impact on gut health	Poultry performance	Immune modulation	AMR reduction	Stress resilience	Experimental model (References)
Anti-*S. aureus*	Improves gut barrier integrity and inhibits pathogen growth by competitive exclusion	Enhances intestinal barrier function	Enhances weight gain; Improves nutrient absorption; Strengthen eggshell	Regulates cytokine activity	Reduces the need for antimicrobials	Oxidative stress reduction	*In vitro* (Rocchetti et al. 2021; Xu et al. 2023; Zhang et al. 2023a; Sajid et al. 2025)
Salmonella reduction	Boosts the host's immune system and causes the production of immunoglobulins	Increases the height of villi	Improves ADG; Improve FCR; Enhances meat flavour	Stimulates IgA production	Reduces pathogen colonization and load, resulting is reduced need of antimicrobials	Heat stress mitigation	*In vivo* and *In vitro* (Lou et al. 2024; Siddiqui et al. 2024; Borovikov et al. 2025; Gorzelanna et al. 2025; Hou et al. 2025; Mateen et al. 2025)
Biofilm disruption	Blocking adherence of the pathogen to the gastrointestinal tract lining	Reduce inflammation	Promote faster growth; Lower feed cost; Improve egg quality	Enhance the activity of phagocytes	Resistance mitigation	Assists in pathogen exclusion	*In vitro* (Shi et al. 2024; Wei et al. 2024; Zang et al. 2025)
E. coli inhibition	Strengthen the gastrointestinal tract lining	Strengthen Tight junction proteins	Promote an efficient growth rate; Optimize digestion; Improve Meat tenderness	T-cell activation	Potential modulation of AMR resistance gene	Ammonia stress relief	*In vivo* and *In vitro* (Xu et al. 2023; Waqas et al. 2024; El-Sharkawy et al. 2025; Herich et al. 2025; Zhong et al. 2025)
Bacteriocin production	Decrease the pH of the gut	Reducing pathogen growth	High ADG; Better Feed conversion; Associated with Increased egg size	Stimulate immune activity	Reduce resistance by lowering the pathogen load	Heat stress relief	*In vitro* (Xu et al. 2023; Touati et al. 2025; Wu et al. 2025)
Anti-*campylobacter*	Inhibit pathogens by depriving them of nutrients by absorbing them	Microbiota diversity	Improve livability; Linked to higher energy efficiency ratio; Improve the meat quality	Maintain Immune homeostasis	Competitive exclusion of pathogens	Reduce environmental stress	*In vitro* (Ruiz et al. 2023; Yuan et al. 2023; Wang et al. 2025b)
Horizontal gene transfer inhibition	May inhibit plasmid-mediated resistance gene exchange	Inhibiting pathogens	Increase weight gain; Enhance feed intake; Improve the quality and quantity	Provides immunotherapeutic support	Reduce AMR spread	Reducing pathogen load	*In vitro* (Sabia et al. 2009; Chang et al. 2022; Sharma and Kim 2024; Li et al. 2025)
Anti - *C. perfringens*	Strengthening the gut lining	Strengthen Tight junction proteins	Improve growth; Increase nutrient efficiency; Improve eggshell quality	Increases cytokine secretion	Resistance mitigation	Decrease disease susceptibility	*In vivo* (Xu et al. 2020; Chang et al. 2022; Chintakovid et al. 2024)
Anti-Listeria *monocytogenes*	Lowering the PH of the gut	Killing harmful pathogens	Increase in weight gain; Improve digestion; Eggs with better shell strength and yolk colour was observed	Promote the proliferation of T & B lymphocytes, and activate immune cells like mononuclear phagocytes	Releasing organic acids like lactic acid that lower PH	Reduce pathogen population	*In vitro* (Prete et al. 2020; Wei et al. 2024; Han et al. 2022)
Quorum-sensing disruption	Interferes with the signalling process between pathogens	Decreases the population of harmful pathogens	Enhances the growth rate; Increases feed intake	Provides immunotherapeutic support	Decreases resistance by lowering the pathogen load	Controls microbial overgrowth	*In vitro* (Han et al. 2022; Liu et al. 2023; Xu et al. 2025)
Host digestive enzyme activity	Boosts digestive processes and disrupts the plasma membrane	Better nutrient absorption	Promote growth; Increases digestion and feed intake; Increase meat production	Enhances phagocytosis of pathogens	Indirectly reduces AMR selection pressure	Indirectly, by depriving pathogens of nutrients	*In vivo* (Guan et al. 2024; Chen et al. 2025; Jiao et al. 2025)
Efflux pump suppression	Downregulate the expression of bacterial efflux pump genes so that they are unable to expel antibiotics	Reduce persistence of pathogens in the GIT	Promote health that leads to better weight gain; Improve nutrient utilization; Improve carcass quality and egg production	Reduce chronic immune activation caused by persistent infections	Reduce AMR by making bacteria more susceptible to antibiotics	Reduce pathogen-induced physiological stress	*In vitro* (Prete et al. 2020; Rocchetti et al. 2021; Meng et al. 2022; Chen et al. 2025)
Reactive oxygen species modulation	Enhances the activity of antioxidant enzymes that reduce oxidative stress in the body	Protects the gut epithelium from oxidative injury	Maintains steady growth; Enhances digestion of feed; Enhances meat shelf life	Balances pro-inflammatory cytokine production	Potential reduction in stress-induced mutation rates linked to resistance development	Reduces oxidative stress	*In vivo* (Nazeer et al. 2021; Xiao et al. 2024; Qamar et al. 2025; Zhang et al. 2025a)
Modulation of antimicrobial peptide expression	Stimulates the expression of host defensins and cathelicidins that suppress microbial growth in the body of the host	Reduces the number of pathogens	Promotes growth; Improves FCR by decreasing disease pressure; Enhances meat quality and egg production	Strengthens the immune response	Decreases the reliance on antibiotics by enhancing the natural defence of the host	Reduces pathogen-related physiological stresses	*In vivo* (Rocchetti et al. 2021; Thi et al. 2022; Woldemariam et al. 2024; Gao et al. 2025; Shi et al. 2026)

FCR: Feed Conversion Ratio; ADG: Average Daily Gain

during pelleting, resident intestinal microbiota, and antibiotic exposure are important for effective probiotics (Yaqoob et al. 2022). Hence, experimental results under controlled conditions may not translate effectively under commercial conditions. Another challenge is the optimization of dose rate because there is no specific dose rate for different poultry species of various ages, as different studies use different dose rates of *L. plantarum* in different species of broilers and layers. Additionally, its survival under different environmental conditions and stability during feed processing remain essential for consistent results (Xu et al. 2023). Whole-genome sequencing (WGS), combined with antimicrobial susceptibility testing, can help identify acquired AMR genes, assess their potential transferability, and minimize the risk of resistance dissemination to pathogenic bacteria (Suthar 2025). However, information on these aspects under different field conditions is still insufficient. Therefore, *L. plantarum* can be used as a probiotic in poultry to mitigate AMR if these challenges can be addressed and overcome (Garfias et al. 2025).

In the coming years, *L. plantarum* could be a promising candidate in poultry probiotic technology. A key technological advancement would be introducing modern delivery systems, such as microencapsulation, to improve survival and efficiency of probiotic strain by protecting it during feed processing, storage, harsh gut environment (Sebouai et al. 2024; Laopiem et al. 2025). Additionally, the safety of *L. plantarum* cannot be generalized across species and must be established individually for each strain through comprehensive assessment of antimicrobial resistance genes and their transferability, virulence-associated factors, hemolytic activity, and other relevant safety characteristics before its application in poultry. Furthermore, combining it with other feed additives such as phytogenics, prebiotics, and organic acids may significantly boost its activity through synergism (Sajid et al. 2024; Noor et al. 2025). A combination of omics technologies, including genome sequencing and metagenomics, can improve poultry health and strengthen AMR control by identifying strains that inhibit pathogenic microorganisms, reduce disruption of beneficial microorganisms, and decrease the dissemination of transferable antimicrobial resistance genes (Ferrocino et al. 2023; Zhang et al. 2025b). Furthermore, future studies need to focus on the development of strain-specific probiotics suitable for different poultry species, age groups, and production systems (Nouri et al. 2024; Hou et al. 2025). Large-scale, field-based trials should be conducted to determine whether the developed probiotics formulation produces similar effects under commercial production conditions.

8. Conclusions

The application of *L. plantarum* as a probiotic in poultry may be effective in mitigating AMR. Its supplementation may minimize the dependence on sub-therapeutic antibiotic levels by modulating gut microbiota, strengthening the immune response, and inhibiting pathogenic colonization. It also produces compounds such as bacteriocins and organic acids that inhibit pathogen growth, which may reduce selection pressure favouring the emergence of antibiotic-resistant strains. Additionally, its ability to survive in the GIT conditions of poultry may enhance its practical applicability. It improves growth rate, enhances meat quality, and promotes a healthy flock. Despite nutritional benefits and clinical applications, further research is needed to determine the optimum dose, strain-specific effects, and analyze synergistic effects with other feed additives to improve its efficacy under commercial condition.

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