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Precision Nutrition Strategies to Reduce Antibiotic Use and Improve Gut Health in Broiler Chickens

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Abstract

The global poultry sector is rapidly transitioning to antibiotic-free production in response to consumer demand for safer, more sustainable products and concerns regarding antimicrobial resistance. Precision nutrition, which involves administering precisely the appropriate nutrients to poultry at precisely the appropriate time and in the appropriate form, is a new approach to reduce antibiotic dependence and maintain productivity. This review summarizes the latest research on nutritional and management strategies that enhance the gut health and resilience of broiler chickens. It focuses on three main areas: (1) functional feed additives (probiotics, prebiotics, synbiotics, phytogenics, organic acids, enzymes, and antimicrobial peptides); (2) precision feeding techniques (phase feeding, digestible amino acid formulation, and nutrient density adjustments); and (3) diagnostic/omics tools (microbiome profiling, nutrigenomics, that enable targeted interventions. The consistent benefits of probiotics, prebiotics, and phytogenic compounds on intestinal barrier function, pathogen suppression, and feed conversion are reported in meta-analyses and reviews, rendering them practicable AGP alternatives under commercial conditions. Precision feeding, which aligns the supply and energy of digestible amino acids with the dynamic growth requirements of the animal, reduces nutrient oversupply, enhances feed conversion, and decreases nitrogen and phosphorus excretion. Feed formulation that incorporates metabolomic and omics indicators improves immunological competence and nutrient utilization by more precisely matching food to bird physiology and gut bacteria. Evidence also suggests that combinations of additives (e.g., enzyme + probiotic; phytogenic + organic acid) frequently outperform single interventions, although responses are contingent upon the baseline health, management, and diet composition of the flock. Our findings suggest that a practical, sustainable approach to reducing antibiotic use without sacrificing performance is offered by precision nutrition, functional additives, and modern diagnostics. Future research should prioritize the development of decision-support tools that translate microbiome and nutrigenomic data into actionable dietary recommendations, standardized trial designs, and cost-benefit analyses in commercial settings.

Key Words: *Alternative to antibiotics, Omic technology, Precision nutrition, AMR, Poultry nutrition, Gut microbiota*

Introduction

The utilization of antibiotic growth promoters (AGPs) has historically enhanced poultry productivity; however, their consistent application has resulted in consumer rejection of antibiotic-treated products, regulatory restrictions, and antimicrobial resistance concerns (Abbas et al., 2026; Akram et al., 2019; Wickramasuriya et al., 2024). Due to this, the poultry industry is transitioning to antibiotic-free systems while simultaneously ensuring production efficiency (Sajid et al., 2023). The integration of precision nutrition, targeted functional feed additives, and modern molecular diagnostics is a promising approach to maintaining flock health and performance in the absence of AGPs (Shehata et al., 2022; Sierżant et al., 2023). This approach involves harmonizing feed composition and delivery to the birds' physiological requirements and gut status (Ong et al., 2024). This review provides a concise summary of the most recent evidence (2019–2025) regarding nutritional strategies, functional additives, and omics tools that facilitate the reduction of antibiotics in poultry production.

Materials and Methods

Prioritizing meta-analyses and high-quality reviews that address AGP alternatives, precision nutrition, microbiome interventions, and nutrigenomics, this review synthesizes recent reviews, systematic reviews, and primary trials from PubMed/PMC, Scopus, and major publishers (2019–2025). Recent sources of significant interest include systematic reviews on microbiome-related nutritional interventions and numerous narrative reviews on precision feeding technologies, phytogenics, and probiotics (Ong et al., 2024; Olayiwola et al., 2025).

Functional feed additives as AGP alternatives

Probiotics, prebiotics and synbiotics

Probiotics and prebiotics have been reported to have beneficial effects on feed conversion and immune markers, as well as to enhance epithelial integrity and competitive exclusion of pathogens (Naeem & Bourassa, 2025; Naimati et al., 2025). Additionally, they modulate gut microbial communities. These effects have been documented in numerous trials and reviews (Gumowski et al., 2025; Mekonnen et al., 2024). Synbiotics, which are a combination of a probiotic and a prebiotic, frequently produce additive effects in terms of pathogen suppression and growth performance (Ibeagha-Awemu et al., 2025). However, the outcome is significantly influenced by the strain, dose, and delivery scheduling.

Phytogenics (plant-derived bioactives) and organic acids

Phytogenic substances (essential oils, phenolics) and organic acids demonstrate antibacterial, anti-inflammatory, and antioxidant properties in the gastrointestinal tract (Gumowski et al., 2025). The reviews emphasize the reduction of pathogen burden and the enhancement of intestinal morphology. Additionally, certain phytogenic–organic acid combinations have demonstrated synergistic effects on meat quality and performance (Asghar et al., 2021; Cai et al., 2025).

Enzymes, antimicrobial peptides and bacteriophages

In antibiotic-free diets, exogenous feed enzymes (e.g., xylanase, phytase, protease) reduce the anti-nutritional effects of plant constituents and enhance nutrient digestibility, thereby indirectly supporting gastrointestinal health and performance (Cai et al., 2025). Bacteriophages and antimicrobial peptides are biological approaches that are specifically designed to combat specific pathogens (Abd El-Hack et al., 2025; Akram et al., 2025). However, they require additional commercial validation before they can be used on a regular basis.

Precision nutrition practices

Phase feeding, digestible amino-acid formulation and nutrient density adjustments

Precision feeding strategies offer diets that are tailored to the specific needs of each stage, based on digestible amino acid and energy requirements rather than imprecise estimations (Asghar et al., 2024). This approach reduces nutrient oversupply and enhances feed conversions (Akram et al., 2025). Performance and environmental outcomes are supported by phase feeding and divided sex/weight-group nutrition, which reduce variance in growth and nutrient waste (Asghar et al., 2022).

Feed form, particle size and physical presentation

Optimization of feed structure promotes gut health and mitigates susceptibility to enteric pathogens in antibiotic-free systems, as physical feed properties (pelleting, particle size) influence gizzard function, intestine transit time, and microbiota (Akram et al., 2021; Konkol et al., 2025).

Diagnostic and enabling technologies: microbiome, nutrigenomics and metabolomics

The characterization of gastrointestinal microbial communities and the host response to diet is now possible due to advancements in 16S/shotgun sequencing, transcriptomics, and metabolomics (Abd El-Hack et al., 2025). Nutrigenomics establishes a connection between dietary components and gene expression patterns that are pertinent to nutrient metabolism and immunity, while metabolomics identifies metabolic biomarkers (e.g., SCFAs, bile acids) that indicate the functional status of the intestine (Nawrot et al., 2025). Targeted additive selection and improved intervention accuracy are made possible by using these omics data into feeding decisions. Simplified biomarkers and decision support systems are necessary for the translation of these findings to on-farm actions.

Synergies and integrated strategies

In complex commercial environments, evidence suggests that combinations of approaches (e.g., enzymes + probiotics, phytogenic + organic acids) frequently offer greater benefits than individual interventions. Precision nutrition enhances the efficacy of additives by facilitating an optimal basal diet, minimizing antagonistic interactions, and reducing nutrient excess that may favour pathogenic microbes (Naımatı et al., 2022).

Practical considerations and barriers

Some important limitations are that the effectiveness of additives might vary from farm to farm, costs need to be taken into account, regulations are not always the same, and trial designs need to be standardized (Asghar et al., 2022). To evaluate the costs of precision feeding systems and additive packages in relation to the savings from reduced medication, enhanced FCR, and product premiums for antibiotic-free meat, economic analyses are required (Abbas et al., 2026). Farmers must undergo training, the supply chain must be reliable to ensure consistent additive quality, and the diagnostics must be user-friendly.

Recommendations for future research

- Commercial trials that are well-designed and conducted across multiple centers, comparing integrated precision nutrition + additive packages to AGP controls.
- The creation of straightforward, validated biomarkers (metabolites or microbial signatures) that anticipate the response to particular additives.
- Cost–benefit and life-cycle assessments that include the reduction of AMR risk and the consideration of environmental impacts (N, P excretion).
- Tools for data-driven decision-support that transform omics and farm metrics into feeding recommendations.

Conclusion

Precision nutrition, when combined with validated functional additives and enabled by microbiome and nutrigenomic diagnostics, provides a scientifically grounded approach to decrease antibiotic dependence in poultry production without compromising performance. The adoption of omics insights will be contingent upon the production of robust, farm-level evidence, the reduction of diagnostics and additive costs, and the translation of these insights into applicable feeding rules.

Author Contribution Statement

Muhammad Umair Asghat 2025: Data collection, investigation, formal analysis, and writing the original draft, Review and editing

Qurat ul ain Sajid 2026: Project administration, conceptualization, methodology, Review and editing

Sibel Canoğulları Doğan 2026: Review and editing

Martyna Wilk 2026: Review and editing

Mariusz Korczyński 2026: Supervision, review and editing

Conflict of Interest

The authors declare no conflict of interest.

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Not applicable.

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