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Precision Nutrition, Gut Health and Microbiome in Broiler Chickens: Recent Trends toward More Efficient and Sustainable Poultry Production

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Abstract: The poultry industry has developed rapidly in response to the increasing global demand for high-quality animal protein. However, modern poultry production faces several challenges, including increasing feed costs, antibiotic resistance, environmental pollution, heat stress, and the need to improve feed efficiency. Consequently, recent research has increasingly focused on precision nutrition, intestinal health, gut microbiome modulation, alternative feed ingredients, and smart technologies. This review summarizes recent advances in these areas, with particular emphasis on the relationship between dietary interventions, gut microbiota, intestinal barrier integrity, immune function, and productive performance in broiler chickens. Recent evidence indicates that probiotics, prebiotics, synbiotics, postbiotics, fermented feeds, and alternative protein sources may improve gut health and contribute to sustainable poultry production. In addition, heat stress can alter intestinal microbiota and compromise intestinal integrity, highlighting the importance of nutritional and management strategies for maintaining gut function under challenging environmental conditions. The integration of precision nutrition with artificial intelligence, sensors, and computer-vision technologies represents another promising direction for modern poultry production. Overall, future poultry systems are expected to increasingly integrate nutrition, microbiome management, environmental monitoring, and artificial intelligence to improve productivity, animal health, welfare, and sustainability.

Keywords: *Broiler chickens; precision nutrition; gut microbiome; gut health; probiotics; heat stress; sustainable poultry production; artificial intelligence.*

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Introduction

Broiler production is one of the most important sectors of modern animal agriculture because of the rapid growth rate, short production cycle, and high feed efficiency of broiler chickens. Nevertheless, intensive poultry production is increasingly challenged by high feed costs, environmental concerns, antibiotic resistance, heat stress, and the need to maintain bird health and welfare. Recent reviews emphasize that sustainable poultry production requires the integration of alternative feed resources, improved feed efficiency, precision technologies, waste management, and biotechnology rather than reliance on a single production strategy [1].

Nutrition is one of the most important factors affecting the economic efficiency of broiler production because feed accounts for a major proportion of production costs. Recent research has highlighted the importance of improving nutrient utilization and developing more precise approaches to meeting the nutritional requirements of poultry [2].

At the same time, increasing restrictions on the use of antibiotics as growth promoters have stimulated research into nutritional alternatives capable of maintaining intestinal health and productive performance. Probiotics, prebiotics, synbiotics, postbiotics, phytogenic compounds, organic acids, and fermented feeds have consequently received considerable attention [3,4].

The gut microbiome is now recognized as an important component of poultry health. It interacts with the intestinal epithelium, immune system, and dietary components and can influence nutrient digestion, pathogen exclusion, intestinal integrity, and productive performance [5].

Therefore, the objective of this review is to summarize recent developments in precision nutrition, gut microbiome modulation, antibiotic alternatives, alternative feed ingredients, heat-stress mitigation, and artificial intelligence in broiler production, with emphasis on their potential contribution to efficient and sustainable poultry production.

Literature Review

Gut Microbiome and Its Role in Broiler Production

The gastrointestinal tract of chickens contains a complex community of microorganisms that perform several important functions, including fermentation, production of short-chain fatty acids, competition with pathogenic microorganisms, and regulation of intestinal and immune functions. Therefore, the gut microbiome is no longer considered merely a collection of microorganisms inhabiting the digestive tract; rather, it is increasingly recognized as an important biological component affecting bird health and productive efficiency.

Recent studies have demonstrated that dietary interventions can be used to manipulate the gut microbiome toward a microbial composition and metabolic activity that are more favorable for bird health. These interventions include probiotics, prebiotics, synbiotics, postbiotics, phytogenic additives, and fermented feed ingredients. Although these strategies act through different mechanisms, their common objectives are to improve microbial balance, strengthen intestinal barrier function, and reduce the colonization of pathogenic bacteria[5].

An important recent development is the shift from the general concept of adding beneficial bacteria toward a more targeted approach known as **precision microbiome modulation**. This approach aims to influence specific microbial functions, such as the production of short-chain fatty acids, rather than simply increasing the abundance of microorganisms considered beneficial[6]. Recent research on precision biotics suggests that directing microbial metabolic activity toward compounds such as propionate and butyrate may improve productive performance and reduce the effects of intestinal inflammation in broilers.

Probiotics, Prebiotics, Synbiotics and Postbiotics

Probiotics are among the most extensively investigated alternatives to antibiotic growth promoters. They consist of live microorganisms that can provide beneficial effects when administered at appropriate levels. Their proposed mechanisms include competitive exclusion of pathogens, production of antimicrobial compounds, modulation of intestinal microbiota, improvement of epithelial barrier function, and regulation of immune responses [3].

A recent review by Naeem and Bourassa [3] emphasized that probiotics may improve poultry productivity and gut health through microbiome modulation, particularly during the early stages of life. However, the response to probiotics depends on the microbial strain, dose, route of administration, diet, and environmental conditions.

More recently, Yue et al. [4] reviewed probiotics, prebiotics, synbiotics, and postbiotics as potential strategies for maintaining gut health in livestock and poultry. These interventions can influence microbial populations, intestinal barrier integrity, immune regulation, and the production of beneficial microbial metabolites.

Evidence from experimental studies also supports the potential of compound probiotics. Zhang et al. [7] reported that a new compound probiotic affected growth performance, antioxidant capacity, intestinal health, gut microbiota, and microbial metabolites in broilers.

Furthermore, a recent meta-analysis found that Bacillus-based probiotics may provide relatively consistent improvements in broiler feed conversion compared with some other probiotic groups, although responses varied according to probiotic genus, duration, diet, breed, and production conditions [8].

The potential of Bacillus subtilis is particularly relevant in relation to necrotic enteritis. A systematic review and meta-analysis reported that B. subtilis supplementation improved feed conversion ratio and reduced necrotic enteritis lesion scores in challenged broilers, although it did not significantly reduce mortality [9].

These findings indicate that probiotics should not be regarded as a universal replacement for antibiotics but rather as targeted nutritional tools whose effectiveness depends on specific production conditions.

Precision Nutrition and Feed Efficiency

Precision nutrition aims to provide nutrients according to the actual requirements of birds while considering age, growth stage, environmental conditions, health status, and production objectives. The approach seeks to reduce nutrient oversupply while maintaining growth and feed efficiency.

Recent research has identified the practical implementation of precision feeding as one of the major challenges facing poultry nutrition. Accurate estimation of nutrient requirements and the development of reliable feeding technologies remain necessary before precision nutrition can be widely implemented at commercial scale [2].

The integration of precision nutrition with microbiome research provides an additional opportunity. Dietary nutrients do not act independently of the gut microbial ecosystem; rather, microbial communities can influence nutrient availability and metabolism. Therefore, future nutritional programs may increasingly consider both the nutritional requirements of the host and the functional characteristics of the intestinal microbiome.

Improving feed efficiency also has environmental benefits because more efficient nutrient utilization can reduce nutrient excretion and decrease the environmental burden associated with poultry manure.

Alternative Feed Ingredients and Sustainable Poultry Production

The increasing cost and environmental impact of conventional feed ingredients have stimulated interest in alternative sources of protein and energy. Potential alternatives include insects, algae, single-cell proteins, agricultural by-products, food-processing residues, and other unconventional feed resources.

A comprehensive review of sustainable poultry production highlighted alternative feed resources, including insect-based proteins, single-cell proteins, algae, and food-waste-derived ingredients, as important components of future sustainable poultry systems [1].

Algae are particularly interesting because they can provide protein, fatty acids, minerals, pigments, and other bioactive compounds. Abdel-Wareth et al. [10] reviewed the potential of algae as alternative protein sources in poultry diets and concluded that algae may contribute to nutritional value, sustainability, and disease resistance, although cost, availability, inclusion level, and nutritional variability remain important limitations.

Experimental evidence also indicates that microalgae can partially replace soybean meal in broiler diets. Zampiga et al. [11] investigated Arthrospira spp. (Spirulina) as a partial soybean meal substitute and demonstrated that its effects depended on inclusion level and feeding period, with some levels maintaining performance while higher inclusion affected feed conversion and amino acid digestibility.

Fermented feed is another promising approach. Fermentation can increase nutrient bioavailability, reduce antinutritional factors, produce beneficial metabolites, and influence gut microbial populations. A recent review concluded that fermented feed may improve growth performance, nutrient absorption, gut morphology, and microbial balance, although fermentation procedures need further optimization [12].

Thus, alternative feed ingredients should be evaluated not only according to their nutrient composition but also according to digestibility, antinutritional factors, effects on gut microbiota, production cost, and environmental sustainability.

Heat Stress, Gut Health and Nutritional Strategies

Heat stress is one of the major environmental challenges affecting poultry production, particularly in hot and arid regions. Elevated environmental temperatures can reduce feed intake, body weight gain, and production efficiency and can negatively affect intestinal function.

Recent experimental evidence indicates that heat stress can alter the intestinal microbiota of broilers. Campos et al. [13] demonstrated that heat stress and reduced feed intake were associated with changes in the cecal and ileal microbiota of broiler chickens.

Another recent study showed that heat stress can induce temporal changes in the cecal microbiome and was associated with changes in host intestinal serotonin responses [14].

Heat stress may also increase intestinal permeability. Barekatain et al. [15] reported that heat stress increased intestinal permeability in broilers, demonstrating the potential effect of environmental stress on intestinal barrier function.

Nutritional strategies are therefore increasingly investigated as part of heat-stress management. Recent experimental research demonstrated that supplementation with Bacillus subtilis combined with garlic improved feed intake, weight gain, feed conversion ratio, antioxidant status, and some immune parameters in heat-stressed broilers [16].

These findings suggest that effective heat-stress management requires an integrated strategy combining environmental control, water management, appropriate stocking density, ventilation, and targeted nutritional interventions.

Fermented Feed and Functional Nutrition

Fermented feed has recently received increasing attention because it may simultaneously influence nutrient availability and intestinal microbial ecology. During fermentation, microorganisms can produce organic acids, enzymes, peptides, and other metabolites that may improve feed quality.

A recent review found that fermented feed can increase nutrient bioavailability, reduce antinutritional factors, stimulate beneficial lactic acid bacteria, and reduce some pathogenic microorganisms [12].

However, the effects of fermented feed are not always consistent. Factors such as fermentation substrate, microbial inoculum, fermentation duration, moisture content, temperature, and storage conditions can influence the final product. Consequently, standardization of fermentation protocols is necessary for reliable commercial application.

Future developments in precision fermentation and multi-strain microbial inoculation may provide more consistent outcomes and allow the production of fermented feeds with specific nutritional and microbiological characteristics.

Artificial Intelligence and Precision Poultry Farming

Artificial intelligence (AI), computer vision, sensors, and automated data analysis are among the most recent technologies being introduced into poultry production. These technologies can be used to monitor bird behavior, movement, feed and water consumption, environmental conditions, growth, and welfare.

Paneru et al. [17], in a recent 2026 review, described artificial intelligence as an important component of precision poultry farming and discussed its potential applications, challenges, and future development.

AI-based systems may help farmers detect abnormal behavior or changes in environmental conditions before severe production losses occur. The integration of data from cameras, sensors, environmental monitors, and production records may support more accurate and timely management decisions.

However, several challenges remain, including the cost of technology, data quality, model validation, differences among poultry houses, and the need for large datasets representing different breeds, climates, and production systems.

In the future, AI could potentially integrate nutritional, microbiome, environmental, behavioral, and health data into predictive models. This could facilitate a transition from reactive farm management to predictive precision poultry production.

Sustainability and Environmental Considerations

Sustainability is becoming an increasingly important objective in poultry production. The environmental footprint of poultry systems is influenced by feed production, manure management, energy consumption, water use, and farm infrastructure.

Recent research emphasizes that sustainable poultry production should integrate improved feed efficiency, alternative feed ingredients, renewable energy, waste management, animal welfare, and precision technologies [1].

Feed-based strategies are particularly important because improving nutrient utilization can reduce nitrogen and phosphorus excretion. Alternative protein sources such as microalgae may also contribute to reducing dependence on conventional feed resources, although their environmental benefits depend on production systems and processing requirements [10].

Recent work on greenhouse-gas mitigation in poultry farming has also highlighted precision nutrition, alternative protein sources, nutrient recycling, renewable energy, and waste-to-energy technologies as potential strategies for reducing environmental impacts [18].

Therefore, sustainable poultry production should be considered as a multidimensional concept that integrates economic efficiency, animal health, environmental protection, and resource conservation.

Challenges and Future Perspectives

Despite significant progress in gut microbiome research, nutritional biotechnology, and precision poultry farming, several challenges remain.

First, responses to feed additives can vary considerably among studies because of differences in microbial strains, doses, diets, breeds, environmental conditions, and health status. Therefore, standardized experimental protocols and commercial-scale validation are needed.

Second, the gut microbiome is highly complex. The presence of a particular bacterial group does not necessarily indicate a direct beneficial effect. Future research should therefore focus more on microbial functions, metabolites, and host-microbe interactions.

Third, precision nutrition requires accurate estimates of nutrient requirements and technologies capable of monitoring individual or flock-level responses. The economic feasibility of these technologies is particularly important for small and medium-sized farms.

Fourth, artificial intelligence requires large, high-quality datasets and reliable validation under commercial conditions. Data integration, privacy, interoperability, and farmer training are additional challenges that must be addressed.

Future research should therefore focus on combining precision nutrition with microbiome analysis, targeted probiotics and postbiotics, alternative feed ingredients, heat-stress mitigation, and artificial intelligence. Such integration may allow poultry producers to develop diets and management strategies that respond dynamically to the nutritional, physiological, environmental, and health status of the flock.

Conclusion

Recent advances indicate that the future of broiler production is moving toward an integrated system based on precision nutrition, gut microbiome management, intestinal health, sustainable feed resources, environmental control, and artificial intelligence.

Probiotics, prebiotics, synbiotics, postbiotics, fermented feeds, and alternative protein sources represent promising tools for improving gut health and production efficiency. However, their effectiveness depends on appropriate selection, dosage, environmental conditions, and the physiological status of the birds.

Heat stress represents an additional challenge because it can negatively affect feed intake, intestinal integrity, and microbial communities. Nutritional interventions combined with effective environmental management may help reduce these effects.

At the same time, artificial intelligence and precision technologies offer new opportunities for monitoring bird health, behavior, environment, and productivity in real time.

Overall, the most important future direction is not the use of a single nutritional additive or technology but the integration of diet, microbiome, immunity, environment, management, and artificial intelligence into a unified precision production system. Such an approach could improve feed efficiency, bird health and welfare, economic performance, and environmental sustainability.

References

1. Bist RB, Bist K, Poudel S, Subedi D, Yang X, Paneru B, Mani S, Wang D, Chai L. Sustainable poultry farming practices: a critical review of current strategies and future prospects. *Poultry Science*. 2024;103(12):104295. doi:10.1016/j.psj.2024.104295.
2. Poultry Nutrition: Achievement, Challenge, and Strategy. 2024. *Advances in Nutrition*. doi/PMID: 39424066.
3. Naeem M, Bourassa D. Probiotics in poultry: unlocking productivity through microbiome modulation and gut health. *Microorganisms*. 2025;13(2):257. doi:10.3390/microorganisms13020257.
4. Yue T, Lu Y, Ding W, et al. The role of probiotics, prebiotics, synbiotics, and postbiotics in livestock and poultry gut health: a review. *Metabolites*. 2025;15(7):478. doi:10.3390/metabo15070478.
5. Terefe Mekonnen Y, Savini F, Indio V, et al. Systematic review on microbiome-related nutritional interventions interfering with the colonization of foodborne pathogens in broiler gut to prevent contamination of poultry meat. *Poultry Science*. 2024;103:103607. doi:10.1016/j.psj.2024.103607.
6. Ducatelle R, Goossens E, Eeckhaut V, Van Immerseel F. The Gordon Memorial Lecture: steering the gut microbiome for improved health and welfare in broilers. *British Poultry Science*. 2025;66(4):419–428. doi:10.1080/00071668.2025.2488014.
7. Zhang M, Li X, Xiao Y, et al. Effects of a new compound probiotic on growth performance, antioxidant capacity, intestinal health, gut microbiota and metabolites of broilers. *Poultry Science*. 2025;104(8):105215. doi:10.1016/j.psj.2025.105215.
8. Meta-analysis of probiotic effects on broiler performance: Bacillus outperforms Lactobacillus with enhanced and longer efficacy in developing regions. 2026. *Journal of Animal Science and Biotechnology*. PMID: 41905067.
9. Ghimire S, Subedi K, Zhang X, Wu C. Efficacy of *Bacillus subtilis* probiotic in preventing necrotic enteritis in broilers: a systematic review and meta-analysis. *Avian Pathology*. 2024. doi:10.1080/03079457.2024.2359596.
10. Abdel-Wareth AAA, Williams AN, Salahuddin M, Gadekar S, Lohakare J. Algae as an alternative source of protein in poultry diets for sustainable production and disease resistance: present status and future considerations. *Frontiers in Veterinary Science*. 2024;11:1382163. doi:10.3389/fvets.2024.1382163.
11. Zampiga M, Laghi L, Soglia F, et al. Partial substitution of soybean meal with microalgae meal (*Arthrospira* spp.—Spirulina) in grower and finisher diets for broiler chickens. *Poultry Science*. 2024;103(8):103856. doi:10.1016/j.psj.2024.103856.
12. Effect of fermented feed on growth performance and gut health of broilers: a review. *Animals*. 2025;15(13):1957. doi:10.3390/ani15131957. PMID: 40646856.
13. Campos PM, Greene ES, Proszkowiec-Weglarz M, Dridi S. Effects of heat stress and depressed feed intake on the cecal and ileal microbiota of broiler chickens. *Poultry Science*. 2025;104(10):105591. doi:10.1016/j.psj.2025.105591.

14. Lyte JM, Jia X, Caputi V, et al. Heat stress in chickens induces temporal changes in the cecal microbiome concomitant with host enteric serotonin responses. *Poultry Science*. 2025;104(3):104886. doi:10.1016/j.psj.2025.104886.

15. Barekatain R, Inhuber V, Sharma N, et al. Intestinal barrier function, caecal microbiota and growth performance of thermoneutral or heat stressed broiler chickens fed reduced crude protein diets supplemented with guanidinoacetic acid. *Poultry Science*. 2025;104(2):104792. doi:10.1016/j.psj.2025.104792.

16. Al-Khalaifah H, Mushtaq M, Shoib M, et al. Mitigating heat stress in broilers: effects of *Bacillus subtilis* probiotic and garlic (*Allium sativum*) supplementation on growth performance, antioxidant status, cecal microbiota and immune response. *Poultry Science*. 2025;104(11):105795. doi:10.1016/j.psj.2025.105795.

17. Paneru B, Dhungana A, Dahal S, Chai L. Artificial intelligence in precision poultry farming: opportunities, challenges, and future features. *Animal Frontiers*. 2026;16(2):41–50. doi:10.1093/af/vfag004.

18. Greenhouse gas sequestration in poultry farming: strategies for sustainable production and environmental impact mitigation. 2026.

19. Li Y, Zhang JL, Chen JQ, et al. Integrative analysis of the microbiome and metabolome of broiler intestine: insights into the mechanisms of probiotic action as an antibiotic substitute. *Probiotics and Antimicrobial Proteins*. 2025;17(5):3482–3494. doi:10.1007/s12602-024-10304-5.

20. Jeong JY, Kim J, Kim M, et al. Effect of probiotics on growth performance, cytokine levels, and gut microbiome composition of broiler chickens for 7 and 35 days. *Journal of Animal Science and Technology*. 2026;68(2):586–602. doi:10.5187/jast.2025.e12.