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Optimization of Probiotic-Supplemented Feeds to Enhance Gut Health and Nutrient Absorption in Broiler Chickens

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Abstract.*The optimization of probiotic-supplemented feeds has gained significant attention as a sustainable alternative to antibiotic growth promoters in poultry production. This study investigates the effects of dietary probiotics on gut health and nutrient absorption in broiler chickens. Probiotics, such as Lactobacillus, Bifidobacterium, and Bacillus strains, are known to enhance intestinal microbial balance, suppress pathogenic bacteria, and stimulate immune responses. A comprehensive approach was applied by formulating feeds supplemented with different probiotic strains and evaluating their impacts on growth performance, feed conversion ratio (FCR), intestinal morphology, and nutrient digestibility. Results showed that probiotic supplementation significantly improved villus height and crypt depth ratio in the small intestine, indicating enhanced absorptive capacity. Additionally, treated broilers demonstrated higher retention of essential nutrients, such as crude protein and energy, compared with the control group. Improvements in weight gain and FCR were consistently observed across probiotic-supplemented treatments, suggesting better feed utilization efficiency. Furthermore, probiotics promoted the growth of beneficial microflora while reducing intestinal colonization of E. coli and Clostridium perfringens, thereby improving overall gut health. These findings highlight the potential of probiotics as a functional feed additive that supports both animal performance and health, while minimizing the risks associated with antibiotic residues and resistance. Optimizing probiotic type, dosage, and delivery in feed formulations is crucial to maximize their benefits for poultry production. In conclusion, probiotic-supplemented feeds represent a promising strategy to improve gut health, nutrient absorption, and production efficiency in broiler chickens, contributing to more sustainable and safe poultry farming practices.*

Keywords*: probiotics, broiler chickens; gut health; nutrient absorption ; feed optimization.*

1. BACKGROUND

Poultry production plays a vital role in meeting the increasing global demand for animal protein. Broiler chickens, in particular, are considered one of the most efficient sources of meat due to their rapid growth and high feed efficiency. However, modern intensive production systems often expose birds to various stressors that compromise gut health and reduce nutrient absorption efficiency. Traditionally, antibiotic growth promoters (AGPs) were used to enhance performance and control pathogenic bacteria, but their continuous use has raised major concerns regarding antibiotic residues in meat products and the development of antimicrobial resistance (Gadde et al., 2018; Khan et al., 2021). These concerns have prompted the search for sustainable alternatives to maintain broiler health and productivity.

Probiotics have emerged as one of the most promising feed additives to replace AGPs. Defined as live microorganisms that confer health benefits to the host when administered in adequate amounts, probiotics have demonstrated significant potential in

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improving intestinal microbial balance, enhancing immune responses, and supporting nutrient utilization (Markowiak & Śliżewska, 2018). In poultry nutrition, probiotic supplementation has been shown to improve feed conversion ratio (FCR), promote the growth of beneficial gut microflora, and suppress colonization of pathogenic bacteria such as Escherichia coli and Clostridium perfringens (Kareem et al., 2017; Al-Khalaifah, 2018). These benefits make probiotics a valuable tool for enhancing gut health and overall broiler performance.

Several studies have reported that probiotics can improve gut morphology by increasing villus height and crypt depth ratio, which contributes to better nutrient absorption (Mountzouris et al., 2019). Moreover, the use of specific strains, such as Lactobacillus, Bifidobacterium, and Bacillus species, has been linked to improved retention of crude protein and energy in broiler diets (Wang et al., 2022). Despite these promising findings, variations in outcomes often occur depending on the probiotic strain, dosage, and method of delivery. This indicates that the optimization of probiotic-supplemented feeds is essential to maximize their potential benefits in poultry production systems.

Although the positive impacts of probiotics on broiler performance are well documented, gaps remain in identifying the most effective probiotic formulations tailored to modern feeding practices. Many previous studies focused on single strains, while the synergistic effects of multi-strain probiotics remain less explored. Additionally, limited research has evaluated the integration of probiotics into practical feed optimization strategies that simultaneously address growth performance, gut health, and nutrient absorption (Shah et al., 2021). Therefore, further research is urgently needed to establish evidence-based formulations and feeding protocols.

This study aims to optimize the use of probiotic-supplemented feeds to enhance gut health and nutrient absorption in broiler chickens. By evaluating the effects of different probiotic strains and dosages on intestinal morphology, microbial balance, and nutrient digestibility, this research provides insights into practical feed formulations that improve broiler performance. The findings are expected to contribute to sustainable poultry farming by reducing dependence on antibiotics while ensuring efficient and safe meat production.

2. THEORETICAL REVIEW

The concept of probiotics is rooted in the theory of microbial balance within the gastrointestinal tract. Probiotics are defined as "live microorganisms which, when administered in adequate amounts, confer a health benefit on the host" (FAO/WHO, 2002). Their primary role is to enhance the intestinal microflora by promoting beneficial bacteria while suppressing harmful pathogens. In poultry nutrition, this microbial balance is critical for maintaining gut integrity, stimulating immune responses, and improving nutrient absorption (Markowiak & Śliżewska, 2018). The mechanism involves competitive exclusion of pathogens, production of antimicrobial compounds, and modulation of host immune responses, ultimately leading to improved gut health.

Gut health theory emphasizes the interaction between intestinal morphology and nutrient absorption. The small intestine, particularly villi and crypts, plays a crucial role in digesting and assimilating nutrients. An increased villus height and villus height-to-crypt depth ratio are associated with higher absorptive capacity and improved feed efficiency (Abdelqader et al., 2013). Probiotic supplementation has been shown to stimulate these morphological changes, thereby enhancing nutrient utilization in broiler chickens. This indicates that intestinal structure is not only a biological determinant of growth but also a responsive marker to dietary interventions.

Nutrient absorption in poultry is also influenced by enzymatic activity and gut microbiota composition. Probiotics have been reported to increase digestive enzyme secretion, such as amylase, protease, and lipase, which in turn promote better feed conversion ratio (Kareem et al., 2017). Furthermore, probiotic-induced modulation of the gut microbiome enhances the fermentation of undigested feed components, leading to improved energy extraction and retention of crude protein (Wang et al., 2022). These findings provide strong theoretical support for probiotics as functional feed additives in broiler nutrition.

Several empirical studies have highlighted the positive effects of probiotics on poultry production. For instance, Mountzouris et al. (2019) demonstrated that a multi-strain probiotic supplementation improved growth performance and reduced pathogenic bacterial colonization in broilers. Similarly, Al-Khalaifah (2018) reported that probiotics could serve as effective alternatives to antibiotic growth promoters by supporting immune function and gut health. However, Shah et al. (2021) noted that

variations in probiotic efficacy depend on strain specificity, dosage, and delivery methods, which underscores the need for optimization.

Based on these theoretical and empirical foundations, it can be inferred that probiotic-supplemented feeds have the potential to enhance gut health and nutrient absorption, thereby improving the productivity and sustainability of broiler production systems. The present study builds upon these theories and previous findings by focusing on the optimization of probiotic feed formulations. The implicit hypothesis underlying this research is that well-formulated probiotic supplementation will improve intestinal morphology, microbial balance, and nutrient utilization, leading to superior growth performance in broiler chickens.

3. RESEARCH METHODOLOGY

This study employed an experimental research design using a completely randomized design (CRD) to evaluate the effects of probiotic-supplemented feeds on gut health and nutrient absorption in broiler chickens. The CRD was chosen due to its ability to minimize bias and provide reliable comparisons across treatments (Montgomery, 2017). Four dietary treatments were formulated: a control diet without probiotics, and three diets supplemented with different probiotic strains (Lactobacillus, Bifidobacterium, and Bacillus spp.) at varying concentrations. Each treatment was replicated across multiple groups of birds to ensure statistical robustness.

The population consisted of commercial broiler chickens (day-old chicks), which were reared under standardized environmental conditions. A total of 240 chicks were randomly allocated into treatment groups, with equal numbers in each replicate. The sample size was determined based on previous experimental studies that reported significant differences in growth and gut health parameters under similar conditions (Mountzouris et al., 2019; Wang et al., 2022).

Data collection focused on both performance parameters and physiological indicators. Performance parameters included body weight gain, feed intake, and feed conversion ratio (FCR), recorded weekly. Physiological indicators involved intestinal morphology (villus height and crypt depth) measured through histological analysis, and nutrient digestibility assessed via the total collection method (Abdelqader et al., 2013). Additionally, microbial counts in the cecum were quantified using selective culture

media to determine populations of beneficial and pathogenic bacteria (Al-Khalaifah, 2018).

The instruments and procedures used in this study followed established standards in poultry nutrition research. Growth performance data were collected using digital weighing scales and feed records, while histological samples were processed according to conventional paraffin embedding and staining techniques (Gadde et al., 2018). Microbial enumeration was conducted by plating serial dilutions on selective agar, and nutrient digestibility was calculated using proximate analysis according to AOAC guidelines (AOAC, 2019).

Data were analyzed using analysis of variance (ANOVA) to detect differences among treatments. When significant differences were observed, means were separated using Duncan's multiple range test at a 5% significance level. Statistical analysis was performed with SPSS software (version 25). The general model for the analysis can be expressed as:

$$Yij=\mu+Ti+\epsilon ij$$

where YijY_{ij}Yij = observed value of the dependent variable, μ\muμ = overall mean, TiT_iTi = effect of the ithi^{th}ith treatment, and ϵij\epsilon_{ij}ϵij = random error (Montgomery, 2017). This model allowed for the evaluation of treatment effects on growth performance, intestinal morphology, nutrient absorption, and microbial balance.

4. RESULTS AND DISCUSSION

Data Collection Process

The study was conducted for a period of 42 days at the Poultry Research Farm of the Faculty of Animal Science, using controlled housing facilities to ensure uniform environmental conditions. Data collection involved weekly measurements of body weight, feed intake, and feed conversion ratio (FCR). Intestinal samples for histological analysis were collected at the end of the trial, while nutrient digestibility was assessed during the last week of the experiment. Microbial counts were determined from cecal samples to evaluate the balance between beneficial and pathogenic bacteria.

Growth Performance

Table 1 summarizes the growth performance of broiler chickens fed probiotic-supplemented diets compared with the control group. Birds receiving probiotics showed significantly higher body weight gain and improved FCR compared with those on the control diet.

Table 1. Growth performance of broilers fed probiotic-supplemented diets (Mean ± SE)

Treatment	Final Body Weight (g)	Feed Intake (g)	FCR
Control (no probiotics)	1950 ± 30	3050 ± 40	1.57
Lactobacillus spp.	2105 ± 28	3075 ± 36	1.46
Bifidobacterium spp.	2120 ± 32	3100 ± 42	1.46
Bacillus spp.	2155 ± 26	3090 ± 39	1.43

Source: Experimental data (2025).

These results are consistent with previous findings that probiotic supplementation enhances broiler growth performance by improving gut health and nutrient utilization (Kareem et al., 2017; Mountzouris et al., 2019).

Intestinal Morphology

Histological analysis showed significant improvements in villus height and villus height-to-crypt depth ratio in birds fed probiotics compared with the control group (Table 2). This indicates enhanced absorptive capacity of the small intestine.

Table 2. Intestinal morphology of broilers at 42 days of age (Mean ± SE)

Treatment	Villus Height (µm)	Crypt Depth (µm)	VH:CD Ratio
Control	1080 ± 20	180 ± 5	6.0
Lactobacillus spp.	1255 ± 18	175 ± 4	7.2
Bifidobacterium spp.	1265 ± 22	170 ± 6	7.4
Bacillus spp.	1290 ± 21	168 ± 5	7.7

Source: Histological analysis (2025).

These findings align with Abdelqader et al. (2013), who reported that probiotics improve intestinal architecture, leading to greater nutrient absorption efficiency.

Nutrient Digestibility And Cecal Microflora

Probiotic-supplemented diets resulted in higher crude protein and energy digestibility compared with the control group. Additionally, microbial analysis revealed increased populations of beneficial bacteria (Lactobacillus spp.) and decreased pathogenic bacteria (E. coli and Clostridium perfringens). This supports the theory of competitive exclusion and microbial modulation by probiotics (Al-Khalaifah, 2018; Wang et al., 2022).

Discussion and Interpretation

The results confirm the hypothesis that probiotic supplementation enhances gut health and nutrient absorption, thereby improving broiler performance. The improvements in growth performance and FCR are in agreement with earlier reports by Gadde et al. (2018) and Shah et al. (2021). Variations among probiotic strains were observed, with Bacillus spp. showing slightly superior performance, consistent with findings that spore-forming bacteria may survive better in feed processing and the gastrointestinal tract (Wang et al., 2022).

The improved villus height-to-crypt depth ratio suggests enhanced epithelial renewal and absorptive surface, which is critical for efficient nutrient assimilation (Abdelqader et al., 2013). The reduction in pathogenic bacterial populations confirms the role of probiotics in gut health maintenance, reducing the risk of enteric diseases and improving food safety (Mountzouris et al., 2019).

Theoretical and Practical Implications

Theoretically, these findings strengthen the role of probiotics in the gut health–performance paradigm in poultry nutrition. Practically, the study highlights the potential for probiotics to serve as sustainable alternatives to antibiotic growth promoters, contributing to safer poultry production systems. Optimizing strain selection and dosage is essential for maximizing these benefits in commercial practice.

5. CONCLUSION AND RECOMMENDATIONS

The present study demonstrated that probiotic supplementation in broiler diets significantly improved growth performance, intestinal morphology, nutrient digestibility, and gut microbial balance compared with the control group. The enhanced villus height-to-crypt depth ratio and increased populations of beneficial bacteria confirmed the positive impact of probiotics on gut health, which in turn supported more efficient nutrient absorption and feed utilization. These findings validate the hypothesis that optimizing probiotic feed formulations contributes to both improved broiler productivity and sustainable poultry farming (Abdelqader et al., 2013; Wang et al., 2022).

In practical terms, the results suggest that probiotics can serve as effective alternatives to antibiotic growth promoters, thereby reducing the risks associated with antibiotic residues and antimicrobial resistance. Among the strains tested, Bacillus spp. showed slightly superior effects, indicating that spore-forming probiotics may be particularly well suited for commercial feed applications due to their stability and resilience (Gadde et al., 2018; Shah et al., 2021). Thus, poultry producers are encouraged to incorporate probiotics as part of integrated feeding strategies aimed at enhancing gut health and production efficiency.

Nevertheless, this study acknowledges certain limitations. The experiment was conducted under controlled research farm conditions, which may not fully represent commercial-scale production environments. In addition, only three probiotic strains were tested, whereas the potential synergistic effects of multi-strain combinations or synbiotic approaches warrant further investigation. Future studies should therefore explore the efficacy of multi-strain probiotic formulations, long-term impacts on broiler immunity and meat quality, and cost-benefit analyses in large-scale operations (Al-Khalaifah, 2018; Mountzouris et al., 2019).

In conclusion, probiotic-supplemented feeds represent a promising strategy for improving gut health, nutrient absorption, and growth performance in broiler chickens. With proper optimization of strain selection and dosage, probiotics may play a central role in advancing sustainable, safe, and antibiotic-free poultry production systems.

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