

# Phase-Specific Nutrient Requirements in Broilers: Implications for Behavior, Gut Health, Performance, Meat Quality, Welfare, and Economics

Md. Emran Hossain<sup>1</sup>, Shilpi Islam<sup>2,\*</sup>

## Abstract

*The broiler industry plays an inevitable role in global food security, requiring optimal formulation strategies tailored to each growth phase, starter, grower, and finisher for sustainable production. This review explores phase-specific nutrient requirements and their implications for broiler performance, meat quality, welfare, and economics. During the starter phase (1–10 days), nutrition focuses on immune development, gut health, and skeletal growth, with high protein and low energy needs. In the grower phase (11–20 days), nutrient strategies prioritize muscle growth and feed efficiency while preventing excessive fat accumulation. The finisher phase (21 days to market) aims for optimal body weight and carcass quality by enhancing high energy and moderate protein intake. Beyond growth, phase-specific nutrition influences behavior, reducing stress-related behaviors like feather pecking. It also enhances gut health, improving nutrient absorption and reducing disease risk through additives like prebiotics and probiotics. Early protein intake affects meat quality by promoting muscle development and improving meat composition through dietary fat. Welfare is enhanced by addressing phase-specific issues, such as leg health, metabolic disorders, and immune system, reducing mortality rates. Economically, tailored diets improve feed conversion ratios, minimize feed waste, and lower veterinary costs, leading to improved profitability. Overall, precise phase-specific nutrient strategies optimize broiler performance, welfare, meat quality, and economic efficiency, supporting sustainable production and meeting consumer demands for high-quality poultry products.*

**Keywords:** Broiler, gut health, meat quality, performance, welfare, poultry behavior, nutrient requirements, economic implications

## INTRODUCTION

The poultry industry is one of the fastest-growing sectors in global animal agriculture, driven by the increasing demand for affordable and high-quality protein sources. Among poultry species, broiler chickens represent the most significant portion of global meat production due to their rapid growth, efficient feed conversion, and adaptability to diverse rearing conditions. However, optimizing broiler production to meet both market demands, and ethical standards requires a deep understanding of their nutritional requirements at each growth phase. The nutrient needs of broilers vary substantially across different life stages, pre-starter, starter, grower, and finisher, each phase playing an important role in determining overall performance, meat quality, and health outcomes.

### \*Author for Correspondence

Shilpi Islam  
E-mail: [shilpi@bsmrau.edu.bd](mailto:shilpi@bsmrau.edu.bd)

<sup>1</sup>Professor, Department of Animal Science and Nutrition, Chattogram Veterinary and Animal Sciences University, Khulshi, Chattogram, Bangladesh

<sup>2</sup>Professor, Department of Animal Science and Nutrition, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh

Received Date: December 28, 2024  
Accepted Date: January 12, 2025  
Published Date: January 18, 2025

**Citation:** Md. Emran Hossain, Shilpi Islam. Phase-Specific Nutrient Requirements in Broilers: Implications for Behavior, Gut Health, Performance, Meat Quality, Welfare, and Economics. *Research & Reviews: Journal of Life Sciences*. 2025; 15(1): 5–15p.

In broiler production, the foundation of high performance begins with precise nutritional management tailored to each growth phase. The

---

starter phase (1–10 days) is a critical window where rapid development of the gastrointestinal system, immune system, and skeletal structure occurs, necessitating highly digestible protein and energy-dense diets [1]. As broilers transition to the starter and grower phases (11–20 days), nutrient requirements shift, with energy-protein ratios needing careful balancing to support continued growth while promoting feed efficiency [2]. The finisher phase (21 days to market) is primarily focused on optimizing muscle deposition and preparing broilers for the market, where specific nutrient formulations influence meat yield and quality [3]. While growth performance is a primary objective, modern broiler production increasingly recognizes the importance of gut health and behavior. The gastrointestinal tract not only facilitates nutrient absorption but also serves as a critical line of defense against pathogens. A well-balanced diet tailored to each growth phase can support the development and maintenance of a healthy gut microbiota, which plays a vital role in disease resistance, nutrient utilization, and overall well-being [4]. Phase-specific nutrition, incorporating prebiotics, probiotics, and appropriate fiber sources, has been shown to enhance gut integrity and reduce incidences of gastrointestinal disorders, thus contributing to improved feed conversion and productivity [5].

Furthermore, behavior and welfare are closely linked to nutritional strategies. Inadequate or imbalanced diets can lead to stress, abnormal behaviors (such as feather pecking or aggression), and compromised welfare, all of which detract from production efficiency [6]. By addressing nutrient needs in each phase, not only can growth be optimized, but animal welfare can also be significantly enhanced, reducing stress and promoting more natural behaviors that align with ethical production standards. Meat quality is a key determinant of consumer satisfaction and market success. Nutritional interventions during specific growth phases can influence important meat characteristics, such as tenderness, juiciness, flavor, and nutrient composition [7]. For instance, amino acid profiles, dietary fats, and vitamins all play crucial roles in muscle development and final product quality. Adjusting nutrient levels in the finisher phase can lead to enhanced meat texture and flavor, contributing to higher consumer demand and premium pricing.

From an economic standpoint, phase-specific nutrition offers considerable opportunities for cost savings and profitability. Efficient nutrient utilization across growth phases minimizes feed wastage, reduces the occurrence of health issues, and enhances overall production efficiency [8]. Balancing the cost of feed ingredients with optimal performance outcomes is crucial for ensuring the economic sustainability of broiler operations, especially considering fluctuating feed prices and market competition. Furthermore, improvements in welfare, health, and meat quality can translate into better market positioning and access to premium markets focused on ethical and high-quality poultry products. Given the complexity of phase-specific nutritional requirements and their far-reaching implications, this review aims to synthesize current research on broiler nutrition and its effects on multiple facets of production, including growth performance, gut health, behavior, welfare, meat quality, and economics. By providing a comprehensive analysis of these interconnected factors, this review will identify key gaps in knowledge, propose strategies for optimizing broiler nutrition, and offer insights into future directions for research and industry practices.

The novelty of this review lies in its comprehensive, integrative approach to examining phase-specific nutrient requirements in broilers, particularly focusing on how tailored nutrition across distinct growth phases impacts multiple interconnected aspects of production, behavior, gut health, performance, meat quality, welfare, and economic sustainability. This review goes beyond traditional growth performance studies by incorporating behavior, welfare, and gut health, offering a holistic view of how nutrition impacts broiler well-being and productivity. It highlights the underexplored areas of phase-specific nutrition's influence on broiler behavior and welfare, which are gaining importance due to ethical standards and consumer preferences. By examining diet's role in shaping gut microbiota and maintaining intestinal integrity across growth phases, the review provides insights into nutrition as a tool for enhancing disease resistance and overall health. Additionally, it links dietary strategies in the finisher phase to improved meat quality and market success.

## **PHASE-SPECIFIC REQUIREMENTS**

Broiler chickens grow rapidly, and their nutrient requirements vary significantly across different phases of their life cycle. These growth phases are typically categorized into three main stages: the starter, grower, and finisher stages, each with distinct nutritional needs aimed at optimizing growth, health, and performance. Proper nutrition management at each stage is crucial for ensuring that broilers reach their genetic potential, maintain health, and produce high-quality meat.

The starter phase (1–10 days) represents the initial stage of the broiler's life, where nutrient intake is primarily focused on supporting immune development, organ growth, and early skeletal formation [9]. During this phase, broilers require high levels of protein (around 23–24%) and energy, as well as adequate amounts of vitamins (such as vitamins A, D, and E) and minerals (calcium, phosphorus, and sodium) to promote healthy growth. The importance of gut health is paramount at this stage, as the gut microbiota is still developing. Inadequate nutrition can compromise gut barrier function, predisposing chicks to infections and poor feed conversion.

In the grower phase (11–28 days), the focus shifts to maximizing growth efficiency and muscle deposition. The protein requirement slightly decreases to around 20–22%, while the energy demand remains high to support the rapid growth spurt. Amino acids, such as lysine, methionine, and threonine, are particularly crucial for muscle protein synthesis during this stage [10]. Additionally, the feed formulation in this phase should balance energy and protein intake to avoid excess fat deposition, which can lead to poor carcass quality. Adequate provision of micronutrients, including zinc, selenium, and magnesium, is essential to support enzymatic functions and metabolic processes.

The finisher phase (29 days to market) is characterized by a greater emphasis on energy for final weight gain and fat deposition [8]. Protein requirements further reduce to around 18–20%, while the energy content of the diet may increase. The finisher diet should also be designed to improve feed efficiency and meat quality, with a focus on ensuring proper lipid metabolism and minimizing oxidative stress [11]. Nutrient imbalances or deficiencies in this phase can negatively affect meat quality, fat content, and overall carcass yield.

While these general guidelines offer a framework for broiler nutrition, the nutrient requirements can vary based on several factors, such as breed, sex, and environmental conditions. Precision nutrition, where the exact nutrient needs of broilers are closely matched to their growth stage and individual characteristics, is an emerging approach that offers potential benefits in both performance and sustainability.

## **IMPLICATIONS FOR BEHAVIOR**

Broiler behavior is intricately linked to their nutritional intake, and phase-specific nutrient adjustments can play a pivotal role in managing both normal and abnormal behaviors. Nutrient imbalances, particularly deficiencies in key amino acids, vitamins, or minerals, can result in stress, leading to the emergence of undesirable behaviors, such as feather pecking, cannibalism, or hyperactivity [12]. Conversely, well-formulated diets that meet the specific needs of broilers during each growth phase can enhance their well-being and reduce the prevalence of stress-induced behaviors.

During the starter phase, nutrition must support the proper development of the central nervous system and immune system. Chicks deprived of sufficient nutrients, particularly essential amino acids like tryptophan, are more likely to exhibit stress-related behaviors [13]. Tryptophan is a precursor to serotonin, a neurotransmitter that plays a critical role in mood regulation. Deficiency in tryptophan or other amino acids can lead to heightened aggression or anxiety-like behaviors [14]. Similarly, a deficiency in B vitamins, such as niacin and thiamine, can impair nervous system development, leading to erratic behaviors in young chicks [15].

In the grower phase, energy and protein levels must be carefully balanced to maintain optimal growth without inducing metabolic stress. Overfeeding energy-rich diets can lead to rapid weight gain, which increases the risk of leg problems and poor mobility, causing frustration and inactivity [16]. On the other hand, providing an energy-deficient diet can result in competition for food and increased aggression. Broilers that are underfed may also engage in feather pecking or cannibalism due to the stress of insufficient nutrient intake. Therefore, ensuring that nutritional levels are neither excessive nor deficient during this phase is crucial for maintaining calm and productive flock behavior.

In the finisher phase, broilers reach maturity, and their behavior is influenced by both their physical condition and the quality of their diet. High-fat diets during this phase can lead to excessive fat deposition, reduced mobility, and increased frustration. Providing adequate levels of fat-soluble vitamins, such as vitamins E and A, helps support immune function and reduce oxidative stress, which can contribute to improved behavior [17]. Moreover, maintaining a balanced calcium-to-phosphorus ratio is essential for preventing leg disorders, which are common in broilers nearing market weight and can lead to pain, reduced mobility, and stress-related behaviors [18].

Behavioral management through nutrition is not only important for welfare but also for economic performance, as stress-related behaviors can lead to injuries, reduced feed intake, and lower productivity. Tailoring nutrient intake to match the specific behavioral needs of broilers during each growth phase can enhance overall flock harmony and lead to more consistent and efficient production outcomes.

## **GUT HEALTH**

Gut health is a critical determinant of broiler performance, and phase-specific nutrition plays a central role in maintaining a healthy and functional gastrointestinal tract (GIT). The gut is responsible for nutrient absorption, immune responses, and maintaining a balanced microbiome, all of which are essential for the overall health and productivity of broilers [19]. Poor gut health can result in nutrient malabsorption, increased susceptibility to diseases, and impaired growth performance.

During the starter phase, the broiler's gut is still developing, and the early colonization of beneficial gut microbiota is vital for establishing a robust immune system and enhancing nutrient absorption [20]. Nutrition during this phase should include easily digestible protein sources, as well as prebiotics, probiotics, and feed additives that promote the growth of beneficial bacteria. Prebiotics, such as mannan-oligosaccharides (MOS) or fructo-oligosaccharides (FOS), help stimulate the growth of beneficial bacteria, while probiotics like *Lactobacillus* and *Bifidobacterium* can help establish a healthy microbial balance [21]. A diet rich in soluble fiber during this phase can also enhance the development of gut villi, increasing surface area for nutrient absorption [22].

In the grower phase, gut health remains a priority, as nutrient absorption efficiency directly influences growth rates and feed conversion ratios (FCR). Protein and energy sources should be carefully selected to minimize undigested feed material that can ferment in the gut, leading to dysbiosis or imbalances in gut microbiota. An overabundance of pathogenic bacteria, such as *Clostridium perfringens*, can lead to enteric diseases like necrotic enteritis, which severely compromise gut integrity and broiler health [23]. Supplementing the diet with organic acids, such as butyric acid or lactic acid, can help lower gut pH and inhibit the growth of pathogenic bacteria, thereby improving gut health and nutrient absorption.

In the finisher phase, maintaining gut integrity and minimizing inflammation is critical for optimizing feed efficiency and meat quality. Diets during this phase should continue to support the gut barrier function through the inclusion of antioxidants, such as vitamins E and C, which help reduce oxidative stress in the gut [24]. Additionally, supplementing with omega-3 fatty acids or other anti-inflammatory compounds can help mitigate gut inflammation, which can occur as broilers near market weight [25]. The inclusion of adequate fiber in the diet during this phase can also help promote gut motility and

prevent constipation or digestive blockages, contributing to overall gut health and improved nutrient absorption.

Gut health is closely linked to broiler performance, and phase-specific diets that prioritize gut health can lead to better feed conversion ratios, enhanced growth rates, and improved meat quality. Maintaining a healthy gut also reduces the reliance on antibiotics and other medical interventions, supporting more sustainable and welfare-friendly broiler production systems.

### **PERFORMANCE OPTIMIZATION**

Performance optimization in broilers is the primary goal of phase-specific nutrient strategies, as growth rate, feed efficiency, and overall productivity are directly influenced by the quality and balance of the nutrients provided. Each growth phase demands a tailored approach to ensure that broilers reach their genetic potential without compromising health or welfare. During the starter phase, the focus is on promoting rapid growth and development, as this stage sets the foundation for future performance. Protein intake is particularly critical, as broilers require sufficient amino acids for muscle growth and organ development [26]. Essential amino acids like lysine and methionine must be provided in adequate amounts, as they are key drivers of protein synthesis. Any deficiencies in these amino acids can lead to reduced growth rates, poor feather development, and an overall decline in productivity [27]. Moreover, the provision of high-quality feed ingredients that are easily digestible is important for maximizing nutrient uptake and minimizing early mortality.

In the phase of growth, broilers experience their most rapid growth, and nutritional strategies must aim to optimize feed conversion efficiency. Balancing protein and energy levels is essential to prevent overfeeding or underfeeding, both of which can negatively impact performance. High-energy diets can lead to excessive fat deposition, which can reduce feed efficiency and carcass quality [28]. Conversely, energy-deficient diets can slow down growth and lead to poor feed conversion ratios (FCR). Amino acid supplementation, particularly with limiting amino acids like threonine and valine, is often required during this phase to optimize growth without leading to excess nitrogen excretion [29].

In the finisher phase, performance optimization involves maximizing final body weight and ensuring high-quality meat production. While the protein requirement decreases, energy intake becomes a greater focus, as broilers accumulate fat and reach market weight. Feed ingredients that provide high levels of unsaturated fatty acids can improve feed efficiency and enhance meat quality by increasing the proportion of lean muscle relative to fat [11]. Additionally, ensuring adequate levels of micronutrients, such as zinc, copper, and selenium, is essential for maintaining metabolic processes and preventing performance-related issues, such as oxidative stress or immune dysfunction.

Optimizing performance across the different growth phases requires a fine-tuned approach to nutrition, where the exact nutrient requirements of broilers are met at each stage. This not only enhances growth rates and feed efficiency but also contributes to the economic viability of broiler production by reducing feed costs and improving overall productivity.

### **MEAT QUALITY**

Meat quality is a critical aspect of broiler production, and nutrition plays a central role in determining the final quality attributes of the meat. Phase-specific nutrient strategies can influence several key characteristics of broiler meat, including tenderness, flavor, juiciness, and the composition of lean muscle and fat [30]. During the *starter phase*, the primary focus is on promoting lean muscle development and ensuring that nutrient imbalances do not negatively affect meat quality. Adequate protein intake, particularly essential amino acids, is crucial for muscle protein synthesis, which directly influences the texture and tenderness of the meat [8]. Deficiencies in key nutrients during this early phase can lead to poor muscle development, resulting in tougher, less desirable meat. Additionally, providing sufficient antioxidants, such as vitamins E and C, can help prevent oxidative damage to muscle tissues, which can negatively impact meat quality [31].

In the grower phase, nutrient intake must be carefully managed to prevent excessive fat deposition, which can reduce meat quality by increasing the proportion of subcutaneous and intramuscular fat [32]. While some fat is necessary for flavor and juiciness, excessive fat can lead to poor carcass yields and lower consumer acceptance. Nutrient strategies during this phase should focus on providing balanced levels of protein and energy to support muscle growth without promoting excessive fat accumulation [8]. Supplementing with omega-3 fatty acids or other polyunsaturated fats can also improve the lipid profile of the meat, leading to healthier, more marketable products [33].

In the finisher phase, the focus shifts to maximizing meat yield and ensuring high-quality carcasses. Nutrient adjustments during this phase can influence several important meat quality traits, including color, pH, and water-holding capacity. For example, diets high in unsaturated fats can improve the oxidative stability of the meat, leading to longer shelf life and improved flavor [34]. Additionally, providing adequate levels of minerals like zinc and selenium can enhance the antioxidant capacity of the meat, preventing lipid oxidation and improving overall meat quality [35].

The nutrient composition of broiler diets can also influence post-slaughter characteristics, such as drip loss, which affects the juiciness and tenderness of the meat [36]. Phase-specific nutrition strategies that prioritize lean muscle growth and minimize oxidative stress can lead to superior meat quality, with better texture, flavor, and consumer appeal.

## WELFARE ISSUES

Broiler welfare is a growing concern in modern poultry production, and nutrition plays a key role in addressing many of the welfare challenges that broilers face. Nutrient imbalances or deficiencies can lead to a variety of welfare issues, including skeletal deformities, metabolic disorders, and compromised immune function [37]. Phase-specific nutrition strategies offer a proactive approach to improving broiler welfare by providing the necessary nutrients to support healthy growth and prevent welfare-related problems.

During the starter phase, welfare considerations focus on promoting early development and preventing conditions like early mortality or weak bone development. Adequate levels of calcium, phosphorus, and vitamin D3 are essential for proper skeletal formation [38], while antioxidants, such as vitamins A and E, help support immune function and prevent early infections. Poor nutrition during this phase can lead to conditions like rickets or poor bone mineralization, which can compromise welfare and lead to increased mortality rates [16].

In the grower phase, broilers are at risk of developing metabolic disorders, such as ascites or sudden death syndrome, due to rapid growth and high metabolic demands [39], [40]. Nutrient strategies that provide balanced levels of energy and protein can help mitigate these risks by preventing excessive fat deposition and supporting cardiovascular health. Additionally, ensuring adequate levels of trace minerals, such as selenium and zinc, can help support immune function and reduce the risk of infectious diseases, which can negatively impact welfare [24].

In the finisher phase, welfare considerations shift to managing leg health and preventing conditions like lameness or footpad dermatitis [41]. Overfeeding energy-rich diets can lead to rapid weight gain, which puts additional strain on the broiler's skeletal system and increases the risk of leg deformities [16]. Providing adequate levels of calcium, phosphorus, and vitamin D3 can help support bone health and reduce the incidence of leg problems. Additionally, managing litter quality through appropriate nutrient strategies, such as reducing excess nitrogen in the diet, can help prevent footpad dermatitis, which is a common welfare issue in broilers nearing market weight [42].

Addressing welfare concerns through phase-specific nutrition not only improves the overall well-being of broilers but also contributes to better production outcomes by reducing mortality rates, improving growth performance, and enhancing meat quality.

## **ENVIRONMENTAL ISSUES**

Phase-specific nutrient management plays a crucial role in enhancing the environmental sustainability of broiler production. By precisely adjusting nutrient levels to match the broilers' needs at each growth stage, farmers can minimize nutrient waste, such as nitrogen and phosphorus excretion, which are key contributors to environmental pollution. Excessive nutrient supplementation, common in non-phase-specific feeding strategies, can lead to increased greenhouse gas emissions and water pollution through runoff and leaching [43]. Incorporating phase-specific feeding reduces the overuse of feed ingredients, optimizing resource utilization and decreasing the overall feed conversion ratio. This, in turn, lowers the demand for raw materials, lessens the environmental burden of feed production, and minimizes the carbon footprint of broiler farming. Sustainable feeding practices that align with each growth phase not only promote efficient nutrient use but also contribute to the broader goals of reducing waste, conserving natural resources, and fostering more environmentally responsible poultry production systems [44].

## **ECONOMIC IMPACT**

The economic impact of phase-specific nutrient strategies is a critical consideration for broiler producers, as feed costs represent the largest expense in poultry production. Optimizing nutrient intake across different growth phases can lead to significant cost savings by improving feed efficiency, reducing waste, and enhancing overall productivity [32]. However, it is important to balance the cost of high-quality feed ingredients with the potential economic benefits of improved performance, welfare, and meat quality.

During the starter phase, high-quality feed ingredients that promote early growth and development can lead to better overall performance and reduced mortality rates, resulting in cost savings over the long term. While the cost of providing easily digestible protein sources and essential vitamins and minerals may be higher, the investment pays off through improved growth rates, better immune function, and reduced early mortality [45].

In the grower phase, feed costs can be managed by balancing energy and protein intake to maximize feed efficiency without promoting excessive fat deposition. Nutrient strategies that improve feed conversion ratios (FCR) can lead to significant cost savings, as less feed is required to produce each kilogram of body weight [46]. Additionally, optimizing amino acid supplementation can reduce the need for excess protein, leading to lower nitrogen excretion and reduced environmental impact, which can also have economic benefits in terms of regulatory compliance and sustainability.

In the finisher phase, the focus is on maximizing final body weight and carcass yield while minimizing feed costs. Providing high-energy diets that promote efficient fat deposition and lean muscle growth can lead to better meat quality and higher market prices [8]. Additionally, nutrient strategies that enhance meat quality, such as improving lipid profiles or reducing oxidative stress, can increase the value of the final product, leading to higher profits for producers.

The economic impact of phase-specific nutrient strategies also extends to welfare improvements, as healthier broilers with fewer welfare-related issues, such as leg deformities or metabolic disorders, are more likely to reach market weight and produce high-quality meat. Reducing the incidence of welfare-related problems through proper nutrition can lead to lower veterinary costs, reduced mortality rates, and improved overall productivity, resulting in significant cost savings for producers [47].

In conclusion, phase-specific nutrient strategies offer a comprehensive approach to optimizing broiler performance, meat quality, welfare, and economics. By tailoring nutrient intake to match the specific needs of broilers during each growth phase, producers can achieve better production outcomes, reduce feed costs, and improve the overall sustainability of broiler production systems.

## CONCLUSIONS

Understanding and implementing phase-specific nutrient requirements in broilers is essential for optimizing their growth performance, gut health, and overall welfare. The precise adjustment of dietary components across different growth stages can positively impact feed efficiency, meat quality, and behavior while reducing health complications. By tailoring nutritional strategies to each developmental phase, producers can not only enhance the economic viability of broiler production but also promote sustainable practices that align with animal welfare standards. Future research should further explore the interactions between nutrition, genetics, and environmental factors to refine nutrient recommendations that can support the ever-evolving demands of broiler production systems.

## Limitations

Environmental variability, including temperature and housing conditions, may also influence broiler performance and health, which the study may not have adequately addressed. Additionally, the variability in the nutrient composition of feed ingredients can impact the accuracy of the nutrient requirements identified. Short trial durations may limit the understanding of long-term effects, and while behavioral aspects are discussed, comprehensive assessments could provide deeper insights into welfare impacts. The economic analysis might rely on theoretical models rather than real-world scenarios, potentially reducing practical applicability. Furthermore, focusing on specific nutrients without considering dietary interactions could limit the effectiveness of the recommendations. Finally, if the study involved a narrow range of broiler genotypes, the findings may not be applicable to other breeds. Recognizing these limitations can help direct future research efforts.

## Future Directions

Comprehensive research should explore the interactions among various dietary components for a holistic understanding of their impact on development. Additionally, more detailed investigations into behavioral responses to different nutrient formulations could enhance welfare insights. Including a broader range of genetic lines in research is crucial to determine if nutrient requirements vary among breeds. Studies should also examine how environmental conditions affect the effectiveness of nutrient strategies. Robust economic analyses that reflect real-world scenarios are essential for evaluating the practical implications of these feeding strategies. Furthermore, research on gut health and microbiome interactions with nutrition can provide valuable insights for optimizing performance. Finally, integrating sustainability and welfare assessments will ensure that phase-specific nutrition aligns with ethical farming practices. Addressing these gaps will contribute to more effective and sustainable broiler production.

## REFERENCES

1. Ivanovich FV, Karlovich OA, Mahdavi R, Afanasyevich EI. Nutrient density of prestarter diets from one to ten days of age affects intestinal morphometry, enzyme activity, serum indices and performance of broiler chickens. *Anim Nutr*. 2017;3(3):258–265. doi:10.1016/j.aninu.2017.06.005.
2. Akinbobola. Nutrient Requirement of Broilers. *Livestocking*. 2018;1–11.
3. Sokanyile S. How phase feeding manipulation affects growth performance, feed cost, carcass characteristics and the quality of meat from broilers? [master's thesis]. East London: University of Fort Hare; 2017.
4. Pan D, Yu Z. Intestinal microbiome of poultry and its interaction with host and diet. *Gut Microbes*. 2014;5(1):108–119. doi:10.4161/gmic.26945.
5. Shehata AA, Yağın S, Latorre JD, Basiouni S, Attia YA, El-Naggar K, et al. Probiotics, prebiotics, and phytochemical substances for optimizing gut health in poultry. *Microorganisms*. 2022;10(2):1–34. doi:10.3390/microorganisms10020395.
6. Ncho CM, Berdos JI, Gupta V, Rahman A, Mekonnen KT, Bakhsh A. Abiotic stressors in poultry production: A comprehensive review. *J Anim Physiol Anim Nutr (Berl)*. 2024. doi:10.1111/jpn.14032.
7. Zhao L, Huang Y, Liu Q, Ma D, Hu S, Hu Q, et al. Stage-specific nutritional management and developmental programming to optimize meat production. *J Anim Sci Biotechnol*. 2023;14(1):1–14. doi:10.1186/s40104-022-00805-0.

8. Maharjan P, Hilton K, Waldenstedt L, Young M. Review: Physiological growth trend of current meat broilers and dietary protein and energy management approaches for sustainable broiler production. *Animal*. 2021;15:100284. doi:10.1016/j.animal.2021.100284.
9. Ravindran V, Abdollahi MR. Nutrition and digestive physiology of the broiler chick: State of the art and outlook. *Animals*. 2021;11(10):2795. doi:10.3390/ani11102795.
10. Baker DH. Advances in protein-amino acid nutrition of poultry. *Amino Acids*. 2009;37(1):29–41. doi:10.1007/s00726-008-0198-3.
11. Choi J, Kong B, Bowker BC, Zhuang H, Kim WK. Nutritional strategies to improve meat quality and composition in the challenging conditions of broiler production: A review. *Animals*. 2023;13(8). doi:10.3390/ani13081386.
12. van Krimpen MM, Kwakkel RP, André G, van der Peet-Schwering CMC, den Hartog LA, Verstegen MWA. Impact of nutritional factors on feather pecking behaviour of laying hens in non-cage housing systems. *World Poult Sci Assoc Proc 16th Eur Symp Poult Nutr*. Strasbourg, France; 2007. 415–422.
13. Mindus C, Sánchez-Rodríguez E, Blanchet F, Fumihito A, Bendelac A, et al. L. rhamnosus improves the immune response and tryptophan catabolism in laying hen pullets. *Sci Rep*. 2021;11(1):1–15. doi:10.1038/s41598-021-98459-x.
14. Linh NT, Guntoro B, Qui NH. Immunomodulatory, behavioral, and nutritional response of tryptophan application on poultry. *Vet World*. 2021;14(8):2244–2250. doi:10.14202/vetworld.2021.2244-2250.
15. Burgos S, Bohorquez DV, Burgos SA. Vitamin deficiency-induced neurological diseases of poultry. *Int J Poult Sci*. 2006;5(9):804–807. doi:10.3923/ijps.2006.804.807.
16. Bradshaw RH, Kirkden RD, Broom DM. A review of the aetiology and pathology of leg weakness in broilers in relation to welfare. *Avian Poult Biol*. 2002;83.
17. Shakeri M, Oskoueian E, Le HH, Shakeri M. Strategies to combat heat stress in broiler chickens: Unveiling the roles of selenium, vitamin E and vitamin C. *Vet Sci*. 2020;7(2):71. doi:10.3390/VETSCI7020071.
18. Yang YF, Sun H, Liu L, Zhang Y, Qian Z, et al. Effect of dietary calcium or phosphorus deficiency on bone development and related calcium or phosphorus metabolic utilization parameters of broilers from 22 to 42 days of age. *J Integr Agric*. 2020;19(11):2775–2783. doi:10.1016/S2095-3119(20)63302-0.
19. Qamar A, Qaisrani SN, Saeed M, Iqbal M, Abbas Z, et al. The role of intestinal microbiota in chicken health, intestinal physiology and immunity. *J Anim Plant Sci*. 2020;31(2):342–351. doi:10.36899/JAPS.2021.2.0221.
20. Jha R, Singh AK, Yadav S, Berrococo JFD, Mishra B. Early nutrition programming (in ovo and post-hatch feeding) as a strategy to modulate gut health of poultry. *Front Vet Sci*. 2019;6:82.
21. Zoumpopoulou G, Papadimitriou K, Alexandraki V, Georgalaki M, Anastasiou R, Papandreou N, et al. Probiotics and prebiotics: An overview on recent trends. *Probiotics Prebiotics Anim Heal Food Saf*. 2018:1–34. doi:10.1007/978-3-319-71950-4\_1.
22. Jha R, Mishra P. Dietary fiber in poultry nutrition and their effects on nutrient utilization, performance, gut health, and on the environment: a review. *J Anim Sci Biotechnol*. 2021;12(1):1–16. doi:10.1186/s40104-021-00576-0.
23. Tellez-Isaias G, Kogut MH, Lester H, Wolfenden R, Hargis BM, Bottje WG. Effects of chronic stress and intestinal inflammation on commercial poultry health and performance: A review. *Ger J Vet Res*. 2023;3(1):38–57. doi:10.51585/gjvr.2023.1.0051.
24. Adedokun SA, Olojede OC. Optimizing gastrointestinal integrity in poultry: The role of nutrients and feed additives. *Front Vet Sci*. 2019;5:1. doi:10.3389/fvets.2018.00348.
25. Alagawany M, Elnesr SS, Farag MR, Abd El-Hack ME, Patra AK, Dhama K. Nutritional significance and health benefits of omega-3, -6 and -9 fatty acids in animals. *Anim Biotechnol*. 2022;33(7):1678–90. doi:10.1080/10495398.2020.1869562.
26. Macelline SP, Chrystal PV, Liu SY, Selle PH. The dynamic conversion of dietary protein and amino acids into chicken-meat protein. *Animals*. 2021;11(8):2288. doi:10.3390/ani11082288.

27. Alagawany M, Elnesr SS, Farag MR, El-Saadony MT, Madkour M. Nutritional significance of amino acids, vitamins and minerals as nutraceuticals in poultry production and health: a comprehensive review. *Vet Q.* 2020;41(1):1–29. doi:10.1080/01652176.2020.1857887.
28. Massuquetto A, Panisson JC, Schramm VG, Surek D, Krabbe EL, Maiorka A. Effects of feed form and energy levels on growth performance, carcass yield and nutrient digestibility in broilers. *Animal.* 2020;14(6):1139–1146. doi:10.1017/S1751731119003331.
29. Fancher BI, Jensen LS. Dietary protein level and essential amino acid content: Influence upon female broiler performance during the grower period. *Poult Sci.* 1989;68(7):897–908. doi:10.3382/ps.0680897.
30. Brewer VB, Emmert JL, Meullenet JFC, Owens CM. Small bird programs: Effect of phase-feeding, strain, sex, and debone time on meat quality of broilers. *Poult Sci.* 2012;91(2):499–504. doi:10.3382/ps.2011-01706.
31. Pečjak M, Leskovec J, Levart A, Salobir J, Rezar V. Effects of dietary vitamin E, vitamin C, selenium and their combination on carcass characteristics, oxidative stability and breast meat quality of broiler chickens exposed to cyclic heat stress. *Animals.* 2022;12(14):1789. doi:10.3390/ani12141789.
32. Ahiwe EU, Omede AA, Abdallah MB, Iji PA. Managing dietary energy intake by broiler chickens to reduce production costs and improve product quality. *Anim Husb Nutr.* 2018. doi:10.5772/intechopen.76972.
33. Pisulewski PM. Nutritional potential for improving meat quality in poultry. *Anim Sci Pap Reports.* 2005;23(4):303–315.
34. Bou R, Codony R, Tres A, Decker EA, Guardiola F. Dietary strategies to improve nutritional value, oxidative stability, and sensory properties of poultry products. *Crit Rev Food Sci Nutr.* 2009;49(9):800–822. doi:10.1080/10408390902911108.
35. Ibrahim D, El-Saadony MT, Alagawany M, Patra AK, Tufarelli V. Effect of dietary modulation of selenium form and level on performance, tissue retention, quality of frozen stored meat and gene expression of antioxidant status in Ross broiler chickens. *Animals.* 2019;9(6):342. doi:10.3390/ani9060342.
36. Lilly RA, Schilling MW, Silva JL, Martin JM, Corzo A. The effects of dietary amino acid density in broiler feed on carcass characteristics and meat quality. *J Appl Poult Res.* 2011;20(1):56–67. doi:10.3382/japr.2010-00222.
37. Whitehead CC. Nutrition and poultry welfare. *Worlds Poult Sci J.* 2002;58(3):349–356. doi:10.1079/WPS20020027.
38. Nielsen SS, Alvarez J, Bicout DJ, Calistri P, Drewe JA, Garin-Bastuji B, et al. Welfare of broilers on farm. *EFSA J.* 2023;21(2):7788. doi:10.2903/j.efsa.2023.7788.
39. Gonzales E, Buyse J, Takita TS, Sartori JR, Decuypere E. Metabolic disturbances in male broilers of different strains. 1. Performance, mortality, and right ventricular hypertrophy. *Poult Sci.* 1998;77(11):1646–1653. doi:10.1093/ps/77.11.1646.
40. Julian RJ. Rapid growth problems: Ascites and skeletal deformities in broilers. *Poult Sci.* 1998;77(12):1773–1780. doi:10.1093/ps/77.12.1773.
41. Alabi OM, Osho SO, Ologun AG, Alabi AO, Akinola LA, Adediran AJ, et al. Effect of litter management systems on incidence and severity of footpad dermatitis among broilers at finisher stage. *Transl Anim Sci.* 2024;8(1). doi:10.1093/tas/txad145.
42. Brink M, Janssens GPJ, Demeyer P, Bağci Ö, Delezie E. Reduction of dietary crude protein and feed form: Impact on broiler litter quality, ammonia concentrations, excreta composition, performance, welfare, and meat quality. *Anim Nutr.* 2022;9:291–303. doi:10.1016/j.aninu.2021.12.009.
43. Powers W, Angel R. A review of the capacity for nutritional strategies to address environmental challenges in poultry production. *Poult Sci.* 2008;87(10):1929–1938. doi:10.3382/ps.2008-00090.
44. Moss AF, Chrystal PV, Cadogan DJ, Wilkinson SJ, Crowley TM, Choct M. Precision feeding and precision nutrition: A paradigm shift in broiler feed formulation? *Anim Biosci.* 2021;34(3):354–362. doi:10.5713/ab.21.0034.

45. Ózsvár L, Tisóczki R, Bartha Á, ÍHorváth MK. The cost-benefit analysis of application of vitamin and mineral supplements in broiler chicken production. *Hungarian Agric Eng.* 2017;7410(31):45–51. doi:10.17676/hae.2017.31.45.
46. El-Deek AA, Al-Harhi MA, Shata RF, Emam AR. Alternative feed ingredients in the finisher diets for sustainable broiler production. *Sci Rep.* 2020;10(1):1–9. doi:10.1038/s41598-020-74950-9.
47. Leone EH, Estévez I. Economic and welfare benefits of environmental enrichment for broiler breeders. *Poult Sci.* 2008;87(1):14–21. doi:10.3382/ps.2007-00154.