Journal of Biomedical Sciences | ISSN: 2960-9356
Review Article Peer-review, Open Access

Exact Nutrition in Poultry: Beyond Conventional Nutrient Requirements to Intelligent Feeding Initiatives to Enhance Performance and Gut Health: A Review

Selma Bahjat Kareem [1]

Abstract: Precision nutrition is an advanced way of feeding chicken with a more accurate ratio of nutrients content with the real requirements of poultry in the production cycle. Precision nutrition tries to improve the utilization of nutrients by refining nutrient use by a more adaptable feeding system, including refined phase feeding, diet mixing, the inclusion of functional feed additives, unlike the more conventional feeding systems by which various dietary phases are pursued. This has increasingly become of interest in view of its capacity to enhance growth rates, facilitate gut operations and reduce the amount of nutrients that are excreted. Besides, accuracy nutrition is accompanied by intestinal functionality, microbial balance, and feed efficiency as essential factors of modern poultry growth. Therefore, the substitution of conventional feeding, which is characterized by the usage of nutrients, with intelligent feeding systems can result in more efficient and sustainable as well as healthy poultry production. The review includes the concept of precision nutrition in poultry, its interaction with the traditional models of feeding, and the primary strategies of smart feeding, as well as its implications on the growth performance and the health of the gut.

Keywords: Precision nutrition, poultry, smart feeding strategies, gut health, growth performance, phase feeding, feed efficiency.

[1] College of Medicinal and Industrial Plants, Kirkuk University, Kirkuk, Iraq

1. Introduction

The world food systems are very large in poultry since it supplies the world with the cheap and high quality animal protein as meat and eggs. Continuous genetic perfectioning and development of management have contributed immensely to the modern strains of poultry being much more efficient in growth and feed usage. However, there are also gains in the nutritional demands of birds that overestimate their needs and they have to be adequately provided with all nutrients to become productive, healthy, and sustainable (Choct, 2009; Cervantes, 2015; Ducatelle et al., 2023; Pomar and Remus, 2023).

The traditional poultry feeding programs usually are based on phase feeding whereby limited amount of diets is provided to birds as they develop. Although this approach has been recognized to be successful, it

is not very effective in elucidating the fact that nutrient requirements keep on changing with age, genetic potential, health conditions and environmental conditions. As a result, the birds may fall prey to nutrient over- or under-supply, and it may lead to a reduction in the feed efficiency and an increase in the nutrient excretion (Pope and Emmert, 2001; Rinttila and Apajalahti, 2013; Pomar and Remus, 2023).

In this regard, precise nutrition has emerged as an advanced feeding concept, which aimed at feeding the bird with the appropriate nutrients, quantity, at an appropriate time, concerning actual needs of the bird. The idea behind this plan is to make the use of nutrients, productive efficiency, and environmental impact more efficient by decreasing the amount of nutrients wasted (Pomar & Remus, 2023). Precision nutrition is also very relevant in poultry production where nutrient requirements vary very rapidly throughout the production cycle and notably in regard to energy, amino acids, minerals and vitamins.

The close relationship between the gut health and precision nutrition is one of the most critical factors that have resulted in the recent interest in it. The gastrointestinal tract is pertinent in major digestion, intestinal absorption, immune action, and maintenance of microorganisms. It negatively affects performance, intestinal feed ratio and disease resistance (Choct, 2009; Ducatelle et al., 2018; Ducatelle et al., 2023). In addition, poultry gut microbiota also play a major role in nutrient metabolism and intestinal integrity, and nutritional interventions that enhance a stable microbial environment are gaining traction as playing an important role in effective production (Apajalahti et al., 2004; Borda-Molina et al., 2018; Yadav and Jha, 2019). The Natural bioactive compounds themselves are also getting more academic attention due to the high potential of antioxidant properties and other therapeutic potential, thus becoming a prospective application in nutrition and biomedical research (Mhamad et al., 2025; Mhamad et al., 2025).

This has increased the place of nutrition based techniques in poultry production because of the shift towards the abolishment of antibiotic growth promoters. Functional feed additives which encompass probiotics, prebiotics, organic acids, enzymes and phytogenic compounds have been of interest as a way of enhancing gut health, nutrient digestibility and performance in a commercial environment (Gadde et al., 2017; Teng and Kim, 2018; Jha et al., 2020). Precision nutrition programs that seek to supplement the birds in respect to the intestinal and physiological needs also include these supplements.

Therefore, precision nutrition is a potential approach to changing the poultry nutrition traditionally founded on a set of fixed programs to more adaptive and efficient prospects. It gives the possibility to improve the functionality of growth, enhance gut health, reduce nutrient excretion, and raise the sustainability of poultry growth (Jha and Mishra, 2021; Ducatelle et al., 2023; Pomar and Remus, 2023). In similarity, this review will be on the transition of the traditional nutrient-based feeding to smart accuracy level nutrition of the poultry with active reference to their effect on productive performance and gut health.

2. Methodology

The present review was authored as a literature review in the form of a narrative dedicated to discussing the substitution of the conventional approaches based on nutrition requirements as a feeding method to the precision nutrition measures in the poultry with particular emphasis on the elements of growth performance and gut health. The narrative reviews are adequate to synthesize general and dynamic topics especially in the event that the objective is to amalgamate the findings of other disciplines and possess an interpretive perspective of the prevailing state of the understanding (Grant and Booth, 2009; Gasparyan et al., 2011; Snyder, 2019).

The search of literature was arranged and applied to locate the relevant material on the significant scientific databases, including PubMed, Scopus, Web of science, and Google Scholar. The reason behind the selection of such databases is the fact that they have a broad scope of peer-reviewed articles on the subject of animal nutrition, poultry science, gut health, and precision livestock research. It was built on the principles of open literature search that is typically suggested in synthesis of evidence (Page et al.,

2021; Higgins et al., 2024).

The most important search terms were the following combinations of the keywords: precision nutrition, precision feeding, poultry nutrition, broiler, laying hen, gut health, intestinal health, gut microbiota, feed efficiency, nutrient utilization, phase feeding, functional feed additives, probiotics, prebiotics, enzymes, and organic acids. Searching was narrowed and further enriched with the help of such Boolean operators as AND and OR. The reference lists of the retrieved articles were also screened manually, which identified the additional relevant works, a standard practice when creating the review (Gasparyan et al., 2011; Snyder, 2019).

Only articles written in the English language and related to poultry species namely broilers and laying cocks were included. Original research papers, review articles and credible reports that were peer-reviewed were preferred and needed to discuss nutrient requirements, feeding strategies, gut health, intestinal microbiota, or sustainability topics relating to poultry feeding. Articles that failed to cover poultry, duplicate articles, abstracts of conferences that were not sufficiently elaborated and those articles that had a narrow scope to the review were filtered out. This approach is related to the recommendations of improving the transparency, relevance, and methodological clarity of review articles (Grant and Booth, 2009; Baethge et al., 2019).

The selected literature was examined and filtered on thematic basis of statistical pooling. Evidence was organized by the important themes, including traditional nutrient requirements, phase feeding, the idea of accurate nutrition, intelligent feeding methods, gut health, intestinal microbiota, positive performance, and environmental responsibility. As it was a literature review rather than a systematic review or a meta-analysis, it focused on the critical synthesis of the literature and conceptual integration of the literature rather than the quantitative estimation of the effects (Ferrari, 2015; Snyder, 2019).

The review was developed to improve the quality of reporting taking into consideration the ideas of transparent review reporting. The present article is not a systematic review, yet it was designed as per the generally accepted reporting standards, such as the PRISMA 2020 Statement, particularly, the section that mentions the transparency of the search strategy, selection of the studies, and the explanation of the intensity of the review (Page et al., 2021). In addition to this, narrative reviews were viewed through the prism of overall quality to ensure the reduction of rationale, appropriate reference, and equal interpretation of the evidence (Baethge et al., 2019).

3. Precision nutrition principle in Poultry.

In poultry, precise nutrition refers to the production and feeding of poultry by the more appropriate diets relative to the real nutrient requirements of the poultry according to their age, genotype, physiological status, health status, and production location. Unlike the conventional feeding programs, which were based on limited feeding phases, precision nutrition is also designed to provide nutrients in a more dynamic and accurate way to maximize the nutrient intake and its use, performance, and inappropriate losses of nutrients (Pomar & Remus, 2023; Pope and Emmert, 2001).

The concept of precision nutrition is also developed in relation to precision livestock farming whereby informational and predictive analytics and automated feeding equipment are increasingly used in informing feeding decisions. The method is particularly relevant to the poultry production as the nutrient requirements change rapidly over the short developmental phases of broilers and also across the production phases of laying hens. Therefore, an overload or underloading of the delivery of nutrients can lead to the biology inefficiency, feed prices, and nitrogen and phosphorus release (Pomar & Remus, 2023).

The main notion of a correct nutrition system is that the nutritional requirement of the bird is not constant. The production cycle prevalent in the conventional feeding systems is usually subdivided into huge divisions such as starter, grower and finisher. Although much as this system is practical it cannot clarify the individual fluctuation in the nutrient needs on a daily basis. Past studies on phase feeding

proved that the quality of diet switching could be applied to obtain optimum growth performance and greater feeding efficiency, which led to more complicated accuracy-feeding programmes that are now underway (Pope and Emmert, 2001).

Precision nutrition is also very much related to the effective use of the dietary protein, amino acids, energy, minerals and functional feed constituents. Modern poultry feeds are increasingly relying on systems of digestible amino acids, feed grade amino acid supplementation, and improved formulation of preciseness to restrain excess of the crude protein with no impact on growth and carrasse production. Not only does this have an effect on the efficiency of production, but also on the gut health and environmental sustainability, since the excess of undigested nutrients may result in the adverse effects on the intestinal microbial balance, as well as the increased release of nutrients to the environment (Jha and Mishra, 2021; Ducatelle et al., 2023).

The other important element of the precision nutrition in poultry is the association between the gut well-being and precision nutrition. Gastrointestinal tract deals with the digestion of nutrients, absorption, and barrier of the microbiota population of the intestine, as well as communication. The recent reviews emphasize that the future developments in the sphere of poultry nutrition should not be reduced to the nutrient content of the diets, but also to the effects of the latter on the intestinal ecosystem. In this aspect, precision nutrition is not merely geared to grow to its full potential, but also gut integrity, microbial stability, and immune competence (Ducatelle et al., 2023).

The practical sense of precision nutrition may involve a variety of methods, such as increasing the number of feeding periods, balancing diets according to the daily necessity, making the proportions of nutrients more specific, and including the use of additives that make the digestion process and the activity of the intestines easier. The recent studies on broilers have revealed that the rate of chicken-meat production can be improved through implementation of the precision feeding system whereby the dietary concentrates are mixed on a daily basis; thereby, proving the viability of the idea of precision feeding in the marketplace (Pomar & Remus, 2023; Evaluation of Precision Feeding to Enhance Broiler Growth Efficiency, 2025).

Generally, precision nutrition in poultry is the modification of the fixed feeding programs into the adaptive nutritional management. It is meant to nourish the birds in a more efficient way to increase growth output, higher feed ratios, gut health, and reduce the environmental impacts of poultry production. The concept of precision nutrition is also likely to play an important part in the future feeding programs because the poultry systems will be more data-driven and even sustainability-related (Ducatelle et al., 2023; Jha and Mishra, 2021; Pomar and Remus, 2023).

4. Nutrient Requirement of the Traditional Poultry feeding.

The conventional method of feeding poultry can be reduced to the rationing of livestock with the appropriate amounts of required nutrients to sustain livestock, stimulate growth, mating, and ultimate quality of the products. Real world feeding systems are normally designed on criteria requirement tables and breeding-company, with species, age, stage of production, and projected performance modified. The significant nutrient groups in the poultry diets include energy, protein and amino acids, minerals, vitamins, essential fatty acids and water.

Of these nutrients energy and amino acid are the most crucial variables in formulation of feed as they have a potent influence on the rate of growth, ratio of feed to weight, carcass weight and egg production. In the broiler nutritional dietary energy is often computed as metabolizable energy (though other bases are also used, e.g. the standardized ileal digestible basis) and the concentration of amino acids is also being computed on a standardized ileal digestible basis in order to maximize precision and reduce waste nutrient. The new commercial specifications also emphasize on the ratios of amino acids rather than crude protein alone as an indicator of protein adequacy which can be taken as an indicator of the inadequacy of the crude protein as the measure of protein adequacy.

Protein and amino acids needs also vary greatly depending on the genotype and age. The rapid-growing broilers have increased needs on the digestible amino acids because it assists in attaining accelerated lean tissue accretion and laying hens require not only amino acids to sustain their needs but also to ensure continuous increase in the mass of their eggs. The impact of amino acids recommendation in laying hens varies according to breed, age, egg production and the dietary content and recent reviews have shown that not all of the older systems of recommendation take into consideration the requirements of the modern strains.

Mineral nutrition is also included in the conventional feeding of the poultry. The nutrients that are of special importance are the calcium and phosphorous due to their roles in skeletal formation, formation of eggshell and metabolism control. Broilers have poor calcium or phosphorus that impacts on bone development and performance and in laying hens, the minerals are required to sustain the eggshell integrity during the long production period. Their dietary balance is closely linked with the metabolism of the vitamin D and the effectiveness of the intestine absorption.

The vitamins and the trace elements are necessary in lower quantities and remain obligatory to the normal metabolism, immune system, antioxidant defense, and reproductive ability. Conventionally, vitamin and trace mineral fortification can include a safety measure to address ingredient variance, storage degradation, bioavailability differences and environmental or health tortures. Water is also a basic nutrient and it is majorly involved with digestion, thermoregulation, nutrient transportation, and wastes elimination and thus its quality and availability is valuable to the flock performance.

Although the conventional nutrient requirement systems have enabled the realization of a lot of advancement in the poultry production, they are largely dependent on set feeding phases and mean population. This would mean that they may not give a thorough coverage of the current change in nutrient demands, which occurs during the growth cycle or the production cycle. This is the reason why conventional feeding has remained the foundation to the nutritional requirements of poultry, yet it has also been employed on which more adaptable methods to precision nutrition have been developed.

5. Modification of Conventional Feeding to Precision Feeding System.

The conventional poultry diets are traditionally pegged on a rigid series of the dietary phases that are starter, grower, and finisher poultry diets that are scheduled depending on the conventional requirements of the flock. Although this approach resulted in success in commercial production, it nevertheless does not describe permanent changes in the nutrient demands in growth and production. As a result, the amount of food given to birds may be less than or greater than they require in different stages and this may reduce the feed efficiency and increase the synthesis of nutrients (Pope and Emmert, 2001; Aviagen, 2022).

The change in the transition of precision feeding systems was necessitated by the need to increase the utilization of nutrients and has been more accommodative to the needs of the bird at real-time by adjusting feeding programs. Precision nutrition attempts to offer the appropriate quantity of nutrient of suitable quantity at the correct time either to a flock of birds or, in circumstances, to particular animals. This method is also known as a subset of precision livestock farming and is based on more specific formulation, feed changes on a continuous basis, and in more advanced systems, an automated feed delivery and collection system (Pomar & Remus, 2023).

In poultry this may be triggered by the addition of more feeding stages or a mixed diet in order to better match the nutrient requirements on a daily basis. Therefore, it can be stated that precision feeding is the enhancement of the traditional phase feeding to a more efficient and versatile nutritional system that facilitates performance, decreases feed costs and waste (Pope and Emmert, 2001; Pomar and Remus, 2023).

6. Smart Feeding Strategies

The feeding plans of the poultry are suggested to be launched as smart feeding plans that will be more aligned to the nutrient requirements of the bird either as it grows or produces. Phase feeding is the most commonly used where the diets are changed more frequently during the production cycle to reduce the variation between the supply and the demand of the nutrients. A more advanced system is diet blending, where two or more components of the feed are mixed to provide a more applicable nutrient profile that is more relevant to the daily needs (Pope and Emmert, 2001; Pomar and Remus, 2023).

The other beneficial strategy is the functional feed additives which are utilized in assisting the digestion, nutrient utilization and stability of the intestine. They are probiotics, prebiotics, organic acids, exogenous enzymes, and phytogenic compounds, and are actively debated as nutritional aids to improve feed efficiency and health of the birds, especially when an antibiotic-depleted system has to be considered (Gadde et al., 2017). The moderate level of dietary fiber begins to be considered as the effective measure either because it is able to jumpstart the gastrointestinal development and produce a positive influence on the gut functions under the condition that the source and the dosage are selected carefully (Jha & Mishra, 2021).

Overall, the idea of smart feeding strategies is the viable application of precision nutrition to poultry. These are focused on making the nutrient utilization more effective, maintaining the productive performance, and advancing the gut health according to the more responsive and specific feeding programs (Pomar & Remus, 2023).

7. Growth performance effects.

Precision nutrition may be applied to achieve growth performance, which would guarantee the adequate supply of nutrients in the bird according to the real needs of the bird during the production cycle. Once the diets are more specific, the birds will utilize the nutrients in a better way to build body weight and store the energy as muscles rather than excrete the nutrients. It can augment substantial favorable attributes of body weight gain, feed to ratio, and total output efficiency (Pomar & Remus, 2023).

Among the examples that are the most obvious is the phase feeding which has been discovered to make optimum broiler growth performance through reducing the gap existing between need and what is provided in the diet. Existing studies conducted by Pope and Emmert indicated that the elaborate feeding regimes can maintain optimality of growth, and increases nutritional efficiency when compared to the prolonged traditional feeding regimes (Pope and Emmert, 2001).

Furthermore, a higher accuracy of nutrients would probably play a role in growth indirectly because it would help to maintain activity in the intestine. Considering the fact that the digestion and absorption of nutrients depend heavily on the integrity of the gut, the feeding regimen that eliminates the risk of nutrient oversaturation and reduces the effects of stress on the digestive system might result in a more balanced performance in the conditions of a commercial environment. Recent reviews therefore hint at the fact that precision nutrition has been proven to promote growth because of its accuracy formulation, as well as, is positively correlated with gut health and nutrient utilization (Ducatelle et al., 2023; Pomar and Remus, 2023).

8. Effects on Gut Health

The idea of precision nutrition has a lot to do with the health of the gut due to the high percentage of nutrient digestion and absorption and communication with the gut microbiota in the small intestine. Intestinal health can be considered one of the most important factors of productivity in productive poultry, and the presence of undigested nutrients can promote dysbiosis, inflammation, and loss of the epithelium. In this direction, it can be useful to have feeding programs that have a greater understanding of nutrient delivery to satisfy the needs of the birds and reduced the level of intestinal stability and digestive stress (Choct, 2009; Ducatelle et al., 2023).

A healthy nutritional program can also help to achieve healthier intestinal microbiota. Poultry gut microbiota is also involved in digesting and absorbing nutrients, metabolism and overall performance of the poultry, but the nutritional interventions such as probiotics, prebiotics, organic acid and enzyme are widely used to manipulate the microbial community to a desirable way. Such measures are applied in a precision nutrition model with a more significant goal of improving gut performance and nutrient utilization (Yadav and Jha, 2019; Ducatelle et al., 2023).

Therefore, preciseness nutrition not only influences the gut health in terms of nutrient provision, but also by preserving the intestinal integrity, microbial balance and improving the efficiency of the bird to efficient use of feed. This is one of the reasons why the health of the gut is one of the best outcomes of smart feeding in poultry production (Choct, 2009; Yadav and Jha, 2019; Ducatelle et al., 2023).

9. Conclusion

Another important innovation of poultry diet is precisely nutrition which converts nutrition into fixed conventional programs to more adaptive system nearer to the actual needs of the bird. This plan can boost nutrient utilization and growth output and reduce the unwarranted losses of nutrients in the process of production.

Other than that, there is a close relationship between gut health and precision nutrition whereby more accurate feeding plans could assist in maintaining intestinal functionality, microbe homeostasis, and feed efficiency. Smart feeding options include refined phase feeding, diet mixing and the use of functional feed additives that could offer feasible measures in increasing productivity and sustainability in poultry production.

References

1. Abrams, G. D., Bauer, H., & Sprinz, H. (1962). Influence of the normal flora on mucosal morphology and cellular renewal in the ileum. *Mount Sinai Hospital Journal*.
2. Adhikari, P., Kiess, A., Adhikari, R., & Jha, R. (2020). An approach to alternative strategies to control avian coccidiosis and necrotic enteritis. Journal of Applied Poultry Research, 29(3), 515–534. https://doi.org/10.1016/j.japr.2019.11.005
3. Adil, S., Banday, M. T., Bhat, G. A., Qureshi, S. D., & Wani, S. A. (2011). Effect of supplemental organic acids on growth performance and gut microbial population of broiler chicken. Livestock Research for Rural Development, 23(1), 1–8.
4. Apajalahti, J., Kettunen, A., & Graham, H. (2004). Characteristics of the gastrointestinal microbial communities, with special reference to the chicken. World's Poultry Science Journal, 60(2), 223–232. https://doi.org/10.1079/WPS20040017
5. Aruwa, C. E., Pillay, C., Nyaga, M. M., & Sabiu, S. (2021). Poultry gut health – microbiome functions, environmental impacts, microbiome engineering and advancements in characterization technologies. Journal of Animal Science and Biotechnology, 12, Article 119. https://doi.org/10.1186/s40104-021-00640-9
6. Aviagen. (2022). *Ross broiler nutrition specifications* (2022 ed.). Aviagen. https://aviagen.com/assets/Tech_Center/Ross_Broiler/Ross-BroilerNutritionSpecifications2022-EN.pdf
7. Baethge, C., Goldbeck-Wood, S., & Mertens, S. (2019). SANRA—A scale for the quality assessment of narrative review articles. *Research Integrity and Peer Review, 4*, Article 5. https://doi.org/10.1186/s41073-019-0064-8
8. Bai, S. P., Wu, A. M., Ding, X. M., Lei, Y., Bai, J., Zhang, K. Y., & Chio, J. S. (2013). Effects of probiotic-supplemented diets on growth performance and intestinal immune characteristics of broiler chickens. Poultry Science, 92(3), 663–670. https://doi.org/10.3382/ps.2012-02813

9. Bajagai, Y. S., Klieve, A. V., Dart, P. J., & Bryden, W. L. (2016). Probiotics in animal nutrition: Production, impact and regulation. Food and Agriculture Organization of the United Nations.
10. Borda-Molina, D., Seifert, J., & Camarinha-Silva, A. (2018). Current perspectives of the chicken gastrointestinal tract and its microbiome. Computational and Structural Biotechnology Journal, 16, 131–139. https://doi.org/10.1016/j.csbj.2018.03.002
11. Borda-Molina, D., Vital, M., Sommerfeld, V., Rodehutscord, M., & Camarinha-Silva, A. (2016). Insights into broilers' gut microbiota fed with phosphorus, calcium, and phytase supplemented diets. Frontiers in Microbiology, 7, Article 2033. https://doi.org/10.3389/fmicb.2016.02033
12. Cant, J. P., McBride, B. W., & Croom, W. J. (1996). The regulation of intestinal metabolism and its impact on whole animal energetics. Journal of Animal Science, 74, 2541–2553. https://doi.org/10.2527/1996.74102541x
13. Cengiz, Ö., Köksal, B. H., Tatlı, O., Sevim, Ö., Ahsan, U., Üner, A. G., Ulutaş, P. A., Beyaz, D., Büyükyörük, S., & Yakan, A. (2015). Effect of dietary probiotic and high stocking density on the performance, carcass yield, gut microflora, and stress indicators of broilers. Poultry Science, 94(10), 2395–2403. https://doi.org/10.3382/ps/pev194
14. Cervantes, H. M. (2015). Antibiotic-free poultry production: Is it sustainable? Journal of Applied Poultry Research, 24(1), 91–97. https://doi.org/10.3382/japr/pfv006
15. Choct, M. (2009). Managing gut health through nutrition. British Poultry Science, 50(1), 9–15. https://doi.org/10.1080/00071660802538632
16. Ducatelle, R., Goossens, E., De Meyer, F., Eeckhaut, V., Antonissen, G., Haesebrouck, F., & Van Immerseel, F. (2018). Biomarkers for monitoring intestinal health in poultry: Present status and future perspectives. Veterinary Research, 49, Article 43. https://doi.org/10.1186/s13567-018-0538-6
17. Ducatelle, R., Goossens, E., Eeckhaut, V., & Van Immerseel, F. (2023). Poultry gut health and beyond. *Animal Nutrition, 13*, 240–248. https://doi.org/10.1016/j.aninu.2023.03.005
18. European Commission. (2005). Ban on antibiotics as growth promoters in animal feed enters into effect. European Commission Press Release Database.
19. Eyssen, H., & De Somer, P. (1963). The mode of action of antibiotics in stimulating growth of chicks. Journal of Experimental Medicine, 117(1), 127–138. https://doi.org/10.1084/jem.117.1.127
20. Ferrari, R. (2015). Writing narrative style literature reviews. *Medical Writing, 24*(4), 230–235.
21. Food and Agriculture Organization of the United Nations. (n.d.). *Nutrition and feeding*. FAO. Retrieved March 15, 2026, from https://www.fao.org/poultry-production-products/production/nutrition-and-feeding/en/
22. Gadde, U. D., Kim, W. H., Oh, S. T., & Lillehoj, H. S. (2017). Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: A review. *Animal Health Research Reviews, 18*(1), 26–45. https://doi.org/10.1017/S1466252316000207
23. Gaskins, H. R., Collier, C. T., & Anderson, D. B. (2002). Antibiotics as growth promotants: Mode of action. Animal Biotechnology, 13(1), 29–42. https://doi.org/10.1081/ABIO-120005768
24. Gasparyan, A. Y., Ayvazyan, L., Blackmore, H., & Kitas, G. D. (2011). Writing a narrative biomedical review: Considerations for authors, peer reviewers, and editors. *Rheumatology International, 31*(11), 1409–1417. https://doi.org/10.1007/s00296-011-1999-3
25. Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal, 26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

26. Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (Eds.). (2024). *Cochrane Handbook for Systematic Reviews of Interventions* (Version 6.5). Cochrane.

27. Jha, R., & Berrocoso, J. D. (2015). Review: Dietary fiber utilization and its effects on physiological functions and gut health of swine. Animal, 9(9), 1441–1452. https://doi.org/10.1017/S1751731115000919

28. Jha, R., & Mishra, P. (2021). Dietary fiber in poultry nutrition and their effects on nutrient utilization, performance, gut health, and on the environment: A review. *Journal of Animal Science and Biotechnology, 12*, Article 51. https://doi.org/10.1186/s40104-021-00576-0

29. Jha, R., Das, R., Oak, S., & Mishra, P. (2020). Probiotics (direct-fed microbials) in poultry nutrition and their effects on nutrient utilization, growth and laying performance, and gut health: A systematic review. Animals, 10(10), 1863. https://doi.org/10.3390/ani10101863

30. Jha, R., Fouhse, J. M., Tiwari, U. P., Li, L., & Willing, B. P. (2019). Dietary fiber and intestinal health of monogastric animals. Frontiers in Veterinary Science, 6, Article 48. https://doi.org/10.3389/fvets.2019.00048

31. Klasing, K. C., Dozier, W. A., III, Mateos, G. G., Persia, M. E., Walzem, R. L., Sakomura, N., Reis, M., Viana, G., Riveros, R., Elkin, R. G., Angel, C. R., & Korver, D. R. (2025). Informal nutrition symposium: Overview of the nutrient requirements of poultry, 10th revised edition. *Journal of Applied Poultry Research*. Advance online publication. https://doi.org/10.1016/j.japr.2025.100616

32. Knarreborg, A., Simon, M. A., Engberg, R. M., Jensen, B. B., & Tannock, G. W. (2002). Effects of dietary fat source and subtherapeutic levels of antibiotic on the bacterial community in the ileum of broiler chickens at various ages. Applied and Environmental Microbiology, 68(12), 5918–5924. https://doi.org/10.1128/AEM.68.12.5918-5924.2002

33. Li, L. L., Hou, Z. P., Li, T. J., Wu, G. Y., Huang, R. L., Tang, Z. R., Yang, C. B., Gong, J., Yu, H., & Kong, X. F. (2008). Effects of dietary probiotic supplementation on ileal digestibility of nutrients and growth performance in 1- to 42-day-old broilers. Journal of the Science of Food and Agriculture, 88(1), 35–42. https://doi.org/10.1002/jsfa.2910

34. Lu, J., Idris, U., Harmon, B., Hofacre, C., Maurer, J. J., & Lee, M. D. (2003). Diversity and succession of the intestinal bacterial community of the maturing broiler chicken. Applied and Environmental Microbiology, 69(11), 6816–6824. https://doi.org/10.1128/AEM.69.11.6816-6824.2003

35. Maharjan, P., Martinez, D. A., Weil, J., Suesuttajit, N., Umberson, C., Mullenix, G., Hilton, K. M., Beitia, A., & Coon, C. N. (2021). Review: Physiological growth trend of current meat broilers and dietary protein and energy management approaches for sustainable broiler production. *Animal, 15*(Suppl. 1), 100284. https://doi.org/10.1016/j.animal.2021.100284

36. Mhamad, H. J., & Palani, Z. M. R. . (2025). Pharmacological Active Crocin (Antioxidant) in Saffron: A Review. Spanish Journal of Innovation and Integrity, 38, 8–17. Retrieved from https://sjii.es/index.php/journal/article/view/169

37. Mhamad, H. J., Palani, Z. M. R., & AL-Zubaidy, A. . (2025). Investigation of the Chemical Compounds, Antioxidant Effect and Therapeutic Properties of Crocus sativus L. (Iridaceae): A Review. Indonesian Journal of Innovation and Applied Sciences (IJIAS), 5(1), 89-98. https://doi.org/10.47540/ijias.v5i1.1829

38. Naidu, A. S., Bidlack, W. R., & Clemens, R. A. (1999). Probiotic spectra of lactic acid bacteria (LAB). Critical Reviews in Food Science and Nutrition, 39(1), 13–26. https://doi.org/10.1080/10408699991279187

39. National Research Council. (1994). *Nutrient requirements of poultry* (9th rev. ed.). National Academies Press.

40. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

41. Palani, P. M. R. (2025). Residential crisis in Iraq: The current trends and future prospectus: A review. Spanish Journal of Innovation and Integrity, 38, 121–127.

42. Pomar, C., & Remus, A. (2023). Review: Fundamentals, limitations and pitfalls on the development and application of precision nutrition techniques for precision livestock farming. Animal, 17(Suppl. 2), 100763. https://doi.org/10.1016/j.animal.2023.100763

43. Pope, T., & Emmert, J. L. (2001). Phase-feeding supports maximum growth performance of broiler chicks from forty-three to seventy-one days of age. *Poultry Science, 80*(3), 345–352. https://doi.org/10.1093/ps/80.3.345

44. Rinttilä, T., & Apajalahti, J. (2013). Intestinal microbiota and metabolites—Implications for broiler chicken health and performance. Journal of Applied Poultry Research, 22(3), 647–658. https://doi.org/10.3382/japr.2013-00742

45. Romero, L. F., Zuidhof, M. J., Renema, R. A., Naeima, A., & Giacoboni, G. (2021). Amino acid requirements for laying hens: A comprehensive review. *Poultry Science, 100*(5), 101036. https://doi.org/10.1016/j.psj.2021.101036

46. Roth, N., Käsbohrer, A., Mayrhofer, S., Zitz, U., Hofacre, C., & Domig, K. J. (2019). The application of antibiotics in broiler production and the resulting antibiotic resistance in Escherichia coli: A global overview. Poultry Science, 98(4), 1791–1804. https://doi.org/10.3382/ps/pey539

47. Sakomura, N. K., Del Vesco, A. P., de Paula Dorigam, J. C., & de Castro Silva, E. P. (2025). Amino acid nutrition in poultry: A review. *Animals, 15*(22), 3323. https://doi.org/10.3390/ani15223323

48. Shaufi, M. A., Sieo, C. C., Chong, C. W., Gan, H. M., & Ho, Y. W. (2015). Deciphering chicken gut microbial dynamics based on high-throughput 16S rRNA metagenomics analyses. Gut Pathogens, 7, Article 4. https://doi.org/10.1186/s13099-015-0051-7

49. Sinclair-Black, M. S. M., Garcia, A. R. R., & Ellestad, L. E. (2023). Physiological regulation of calcium and phosphorus utilization in laying hens. *Frontiers in Physiology, 14*, 1112499. https://doi.org/10.3389/fphys.2023.1112499

50. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

51. Stanley, D., Geier, M. S., Denman, S. E., Haring, V. R., Crowley, T. M., Hughes, R. J., & Moore, R. J. (2013). Identification of chicken intestinal microbiota correlated with the efficiency of energy extraction from feed. Veterinary Microbiology, 164(1–2), 85–92. https://doi.org/10.1016/j.vetmic.2013.01.030

52. Teng, P. Y., & Kim, W. K. (2018). Roles of prebiotics in intestinal ecosystem of broilers. Frontiers in Veterinary Science, 5, Article 245. https://doi.org/10.3389/fvets.2018.00245

53. University Extension Service, Mississippi State University. (n.d.). *Water-related factors in broiler production*. Mississippi State University Extension. Retrieved March 15, 2026, from https://extension.msstate.edu/sites/default/files/publications/P2742_web.pdf

54. Van der Waaij, D., Berghuis-de Vries, J. M., & Lekkerkerk-Van der Wees, J. E. (1971). Colonization resistance of the digestive tract in conventional and antibiotic-treated mice. Journal of Hygiene, 69(3), 405–411. https://doi.org/10.1017/S0022172400021653

55. Wang, Y., Zhai, H., Shi, Z., & colleagues. (2025). Evaluation of precision feeding to enhance broiler growth efficiency. *Animals, 15*(16), 2433. https://doi.org/10.3390/ani15162433

56. Yadav, S., & Jha, R. (2019). Strategies to modulate the intestinal microbiota and their effects on nutrient utilization, performance, and health of poultry. *Journal of Animal Science and Biotechnology, 10*, 2. https://doi.org/10.1186/s40104-018-0310-9

57. Yeoman, C. J., Chia, N., Jeraldo, P., Sipos, M., Goldenfeld, N. D., & White, B. A. (2012). The microbiome of the chicken gastrointestinal tract. Animal Health Research Reviews, 13(1), 89–99. https://doi.org/10.1017/S1466252312000138

58. Zhu, X. Y., Zhong, T., Pandya, Y., & Joerger, R. D. (2002). 16S rRNA-based analysis of microbiota from the cecum of broiler chickens. Applied and Environmental Microbiology, 68(1), 124–137. https://doi.org/10.1128/AEM.68.1.124-137.2002