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Poultry Feed Formulation: Principles, Nutrient Requirements and Future Perspectives

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Abstract: *Feed formulation remains a cornerstone of efficient poultry production, as feed costs account for the largest proportion of total production expenses. The objective of poultry feed formulation is to supply birds with balanced nutrients that support optimal growth, egg production, health and feed efficiency while minimizing cost. A deeper understanding of nutrient requirements, ingredient characteristics and innovative formulation strategies is therefore essential for optimizing productivity while addressing emerging demands for sustainability, animal welfare, and food safety. This review provides a comprehensive overview of poultry feed formulation, including fundamental nutritional principles, nutrient requirements of broilers and layers, commonly used feed ingredients, formulation techniques, and major constraints faced by producers. Recent advances and future directions in poultry nutrition are also discussed.*

Keywords: Poultry nutrition, Feed formulation, Broilers, Layers, Nutrient requirements, Feed ingredients

I. INTRODUCTION

Poultry production remains one of the most dynamic and rapidly expanding sectors of animal agriculture, driven by rising global demand for affordable, high-quality protein. Meat and eggs from poultry are essential components of human diets in many regions due to their favorable nutrient profiles, short production cycles, and relatively low production costs compared with other livestock species (Alhotan, 2021). As populations grow and food security becomes a pressing concern, efficient poultry production systems are increasingly critical for meeting nutritional needs while minimizing environmental impacts.

Central to poultry production is nutrition, because feed constitutes the largest portion—often more than 60–70% of total production costs (Pesti & Choct, 2023). Formulating diets that precisely meet the birds' nutrient requirements is vital for achieving optimal growth rates, feed conversion efficiency, reproductive performance in layers, and overall health. Minor imbalances or deficiencies in diets can manifest as poor growth performance, reduced egg production, impaired immunity, and higher mortality, all of which undermine farm profitability and sustainability.

Recent research and industry trends highlight an evolving landscape in poultry nutrition. The traditional focus on cost-minimization is increasingly being complemented by objectives related to sustainability, animal health, and product quality (Pesti & Choct, 2023). For example, alternatives to antibiotics such as probiotics, phytogenic compounds, and essential oils are being investigated as growth-promoting and health-enhancing feed additives due to rising concern over antimicrobial resistance and regulatory restrictions on antibiotic growth promoters (Liu, et al., 2024). Advances in nanotechnology and encapsulation methods have also shown promise in enhancing the stability and bioavailability of natural feed additives, potentially improving gut health and nutrient utilization in poultry (Evci, 2024).

Moreover, there is growing interest in sustainable feed resources that reduce competition between human food and animal feed supplies. Circular economy concepts, such as the use of former foodstuffs and agricultural by-products, are gaining attention as potential raw materials for poultry diets (Evci, 2024). Studies continue to explore precision

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nutrition strategies that better align dietary composition with genetic potential, environmental conditions, and production goals, thereby supporting both economic and ecological sustainability (NRC, 1994; Alhotan, 2021).

Taken together, these developments reflect the multi-faceted challenges and opportunities in modern poultry feed formulation. A deeper understanding of nutrient requirements, ingredient characteristics, and innovative formulation strategies is therefore essential for optimizing productivity while addressing emerging demands for sustainability, animal welfare, and food safety.

Principles of Poultry Feed Formulation

A well-formulated poultry diet must supply adequate energy, protein, essential amino acids, vitamins, minerals, and water. Energy supports maintenance and productive functions, while protein and amino acids are required for tissue growth, feather development, and egg formation. Vitamins and minerals play critical roles in metabolism, skeletal development, and immune function (NRC, 1994). Supplying nutrients in correct proportions is as important as meeting absolute requirements. Excess dietary protein without sufficient energy results in poor protein utilization, whereas mineral imbalances, particularly calcium and phosphorus, can impair growth and bone development. Effective feed formulation therefore considers nutrient interactions rather than individual nutrients in isolation. Nutrient requirements vary with age, body weight, and production purpose. Broiler chickens require high protein and amino acid levels during early growth, while laying hens require increased calcium intake to support eggshell formation. Diets are commonly adjusted across starter, grower, and finisher phases to match these changing requirements (Ravindran, 2013).

Feed formulation aims to achieve nutritional adequacy at the lowest possible cost. The use of locally available ingredients and least-cost formulation techniques is particularly important in regions where feed costs limit poultry production. Nutrient requirements for poultry are influenced by genetics, environment, health status, and management practices. Standard feeding recommendations are commonly based on published guidelines such as those of the National Research Council (NRC, 1994). Energy is the most expensive component of poultry diets and is usually expressed as metabolizable energy (ME). Birds tend to regulate their feed intake according to dietary energy concentration, making accurate energy formulation essential. Protein quality depends on amino acid composition rather than crude protein level alone. Essential amino acids such as lysine and methionine must be supplied in adequate amounts because poultry cannot synthesize them in sufficient quantities (Leeson and Summers, 2005). Calcium and phosphorus are particularly important for bone development and eggshell quality. Trace minerals and vitamins, although required in small amounts, are essential for normal physiological and immune functions.

Table 1: Typical nutrient requirements of broiler chickens

Nutrients	Starter (0–3 weeks)	Grower (4–6 weeks)	Finisher (7–8 weeks)
Metabolizable energy (kcal/kg)	3000	3100	3200
Crude protein (%)	22–23	20–21	18–19
Lysine (%)	1.20	1.10	1.00
Methionine (%)	0.50	0.45	0.40
Calcium (%)	1.00	0.90	0.80
Available phosphorus (%)	0.45	0.40	0.35

Table 2: Typical nutrient requirements of laying hens

Nutrient	Requirement
Metabolizable energy (kcal/kg)	2700–2800
Crude protein (%)	16–18
Calcium (%)	3.5–4.0
Available phosphorus (%)	0.40–0.45

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Lysine (%)	0.80–0.90
Methionine (%)	0.35–0.40

Feed Ingredients Used in Poultry Diets:

Feed ingredients provide the nutrients required to support growth, egg production, health, and feed efficiency in poultry. In recent years, research has continued to focus on improving the use of conventional feed ingredients while also identifying alternative and sustainable feed resources. The choice of ingredients depends on their nutrient content, digestibility, availability, cost, and potential presence of anti-nutritional factors. Energy sources form the largest portion of poultry diets because energy is required for maintenance, growth, and production. Cereal grains such as maize, wheat, sorghum, and barley remain the most commonly used energy ingredients due to their high metabolizable energy content and good palatability. Among these, maize is widely preferred because it is highly digestible and contains low levels of fiber (Leeson and Summers, 2005). However, the increasing cost and competition for cereals between humans and livestock have encouraged the use of alternative energy sources. Agro-industrial by-products such as rice bran and cassava meal are increasingly included in poultry diets, particularly in developing countries, to reduce feed costs. Recent studies have shown that when these ingredients are properly processed and included at appropriate levels, they can partially replace cereals without negatively affecting bird performance (Ravindran, 2013; Pesti and Choct, 2023).

Processing methods such as fermentation have gained attention in the last five years because they can improve nutrient availability and reduce fiber and anti-nutritional factors in unconventional energy sources. Fermented feed ingredients have been reported to enhance gut health and improve feed utilization in poultry (Alhotan, 2021). Protein is required for muscle development, feather growth, enzyme production, and egg formation. Soybean meal remains the most widely used plant protein source in poultry diets due to its high protein content and favorable amino acid profile. It is particularly rich in lysine, which is often limiting in cereal-based diets (NRC, 1994). Other plant protein sources such as groundnut cake, sunflower meal, and cottonseed meal are also used, especially where soybean meal is expensive or scarce. However, these ingredients may contain anti-nutritional factors that limit their inclusion levels unless properly processed or supplemented with enzymes (Panda and Reddy, 2012). In recent years, there has been growing interest in alternative protein sources that are more sustainable. Insect meals, particularly those derived from black soldier fly larvae, have been shown to provide high-quality protein and essential amino acids while reducing environmental impact (Pesti and Choct, 2023). Similarly, microalgae have been investigated as protein-rich feed ingredients with additional functional benefits, although their high cost currently limits widespread use. Minerals and vitamins are required in small amounts but play critical roles in poultry health and productivity. Calcium and phosphorus are particularly important for bone development in growing birds and eggshell formation in laying hens. Calcium is commonly supplied through limestone or oyster shell, while phosphorus is provided through dicalcium phosphate. Vitamins and trace minerals are usually added to poultry diets in the form of premixes to ensure uniform intake. Recent studies emphasize the importance of adequate micronutrient supplementation to support immune function, especially under stressful conditions such as heat stress and disease challenges (Ravindran, 2013). The last decade has seen a shift toward the use of natural feed additives to improve gut health and bird performance, particularly following restrictions on antibiotic growth promoters. Probiotics, prebiotics, organic acids, phytogenic compounds, and enzymes are now widely studied and used in poultry nutrition. Recent research shows that phytogenic additives and essential oils can improve gut morphology, enhance nutrient absorption, and support immune function when included in balanced diets (Pesti and Choct, 2023). Enzyme supplementation has also been shown to improve the digestibility of complex feed ingredients and reduce nutrient excretion, contributing to better feed efficiency and environmental sustainability.

Methods of Poultry Feed Formulation:

Feed formulation methods have evolved from simple manual techniques to advanced computer-based systems that allow precise nutrient balancing and cost optimization. The trial-and-error method is one of the earliest approaches to feed formulation and relies on experience and repeated adjustments. Although simple, this method often leads to

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nutrient imbalances and higher feed costs. The Pearson square method is another traditional approach used to balance a single nutrient, usually crude protein, between two ingredients. While useful for teaching and small-scale feed preparation, it does not account for multiple nutrients or ingredient costs (Leeson and Summers, 2005). Least-cost formulation uses linear programming to identify the combination of ingredients that meets nutrient requirements at the lowest possible cost. This method is widely used in commercial feed mills and allows nutritionists to account for multiple nutrients, ingredient constraints, and market price changes. Least-cost formulation has been shown to significantly improve economic efficiency without compromising bird performance (Panda and Reddy, 2012). Recent advances in poultry nutrition emphasize precision feeding, where diets are adjusted according to bird age, genetic potential, environmental conditions, and health status. Precision nutrition aims to supply nutrients more accurately, thereby reducing nutrient wastage and improving sustainability. The use of real-time performance data and improved nutrient databases has enhanced the effectiveness of modern feed formulation systems (Pesti and Choct, 2023).

Challenges in Poultry Feed Formulation:

Despite advances in nutritional science and formulation technology, several challenges continue to affect poultry feed formulation. Feed cost remains the major constraint in poultry production. Prices of major ingredients such as maize and soybean meal fluctuate due to climate variability, global trade, and competition with human food systems. These fluctuations make it difficult for producers to maintain consistent feed quality and profitability (Ravindran, 2013). The nutrient composition of feed ingredients can vary widely due to differences in variety, processing, storage, and handling. This variability can lead to under- or over-feeding of nutrients if not properly accounted for during formulation. Regular ingredient evaluation and the use of safety margins are therefore important for maintaining consistent performance. Many plant-based feed ingredients contain anti-nutritional factors such as phytate, tannins, and fiber, which reduce nutrient availability. Although processing methods and enzyme supplementation can reduce their effects, optimizing inclusion levels remains a challenge, especially when using unconventional feed resources (Panda and Reddy, 2012). The global move toward reduced or zero use of antibiotic growth promoters has created additional challenges for poultry nutritionists. Birds raised without antibiotics are more susceptible to gut health problems unless diets are carefully formulated and supported with appropriate feed additives. Managing gut health through nutrition has therefore become a major focus of modern poultry feed formulation (Pesti and Choct, 2023).

II. CONCLUSION

Poultry feed formulation is a critical component of efficient and profitable poultry production. A clear understanding of nutrient requirements, ingredient characteristics, and formulation methods is essential for producing balanced and cost-effective diets. Although challenges such as rising feed costs and ingredient variability persist, ongoing advances in nutritional science and feed technology offer opportunities for improving sustainability in the poultry industry.

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