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Review Article

Optimizing Broiler Feed Costs with Guanidinoacetic Acid (GAA)

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Abstract

Rapid genetic progress in modern broilers has increased growth rates, raising demands for efficient energy metabolism and nutrient utilization. Concurrently, rising feed costs necessitate cost-effective nutritional strategies. Guanidinoacetic acid (GAA), a creatine precursor, is a promising feed additive due to its role in cellular energy homeostasis. This review evaluates GAA's biochemical functions, metabolic pathways, and applications in broiler nutrition, focusing on growth performance, feed efficiency, arginine sparing, carcass traits, and economic outcomes. GAA enhances the creatine–phosphocreatine system, improving ATP regeneration and supporting protein synthesis and muscle development. Studies show that GAA supplementation improves body weight gain and feed conversion, particularly under arginine or energy limitations. Its arginine-sparing effect allows more efficient amino acid use and potential reductions in dietary protein and costs. Carcass yield and meat quality also improve. However, GAA efficacy depends on sufficient methyl donors, especially methionine, for conversion to creatine. Overall, GAA supports efficient and sustainable broiler production.

Keywords: Guanidinoacetic acid, broiler chickens, feed cost, feed efficiency, creatine, arginine sparing

INTRODUCTION

Rapid genetic advancement in modern broiler chickens has resulted in extremely high growth rates; for example, contemporary commercial broilers are capable of reaching a live body weight of approximately 2.3–2.4 kg at around 35 days of age, with an average daily weight gain of about 66 g per day. Moreover, genetic selection between 1957 and 2005 increased growth rate by more than 400% while simultaneously reducing feed conversion ratio (FCR) substantially (Zuidhof *et al.*, 2014; Afrin *et al.*, 2024). These developments require highly efficient utilization of dietary energy and protein to sustain rapid growth and overall productivity. To maintain optimal performance, broilers rely on metabolic pathways capable of supporting accelerated muscle development and high productive output.

At the same time, rising prices of major feed ingredients such as corn and soybean meal represent a significant challenge for the poultry industry. For instance, global corn prices were traded at approximately US $428 per bushel in February 2026, while global soybean meal prices ranged from US $292 to US $331 per metric ton, with a historical average of around US $305 per ton, resulting in considerable feed cost pressure in broiler diet formulation (Trading Economics, 2026; Macrotrends, 2026). In addition, volatility in the prices of these basal feed ingredients also affects the production costs of synthetic amino acids used to balance dietary nutrient profiles. This economic pressure has driven nutritionists to explore alternative nutritional strategies that can maintain or enhance growth performance while reducing feed costs.

One such strategy involves the use of functional feed additives that improve energy metabolism. GAA is an endogenous compound synthesized from the amino acids arginine and glycine and serves as the direct biochemical precursor of creatine (Portocarero *et al.*, 2021). Creatine plays a critical role in maintaining cellular energy homeostasis through the phosphocreatine system, which facilitates rapid regeneration of ATP in tissues with high energy demands (Kreider *et al.*, 2021).

In rapidly growing broilers, endogenous creatine synthesis may be insufficient to meet elevated energy requirements, particularly under intensive production conditions. Under such circumstances, dietary supplementation with GAA has gained considerable attention due to its potential to enhance creatine availability, improve energy efficiency, and partially reduce dietary arginine requirements.

Therefore, this review aims to evaluate the role of GAA supplementation in broiler nutrition, with particular emphasis on its effects on growth performance, nutrient utilization, and feed cost optimization. A comprehensive understanding of the metabolic and economic benefits of GAA is expected to provide valuable insights for improving the sustainability and profitability of modern broiler production systems.

BIOCHEMISTRY AND METABOLISM OF GUANIDINOACETIC ACID

GAA is an intermediate metabolite in endogenous creatine synthesis, a compound that plays a critical role in maintaining cellular energy homeostasis (Ostojic *et al.*, 2023). Under normal physiological conditions, GAA is synthesized primarily in the kidneys through a transamidinase reaction between arginine and glycine, catalyzed by the enzyme L-arginine:glycine amidinotransferase (AGAT) (Portocarero *et al.*, 2021). This reaction represents the first and rate-limiting step in creatine biosynthesis and requires an adequate supply of arginine, an amino acid that is frequently limiting in poultry diets.

Following its synthesis, GAA is transported via the bloodstream to the liver, where it undergoes methylation by the enzyme guanidinoacetate N-methyltransferase (GAMT) (Tachikawa *et al.*, 2012). During this step, S-adenosylmethionine (SAM) serves as the primary methyl group donor, converting GAA into creatine, with S-adenosylhomocysteine formed as a by-product (Da Silva *et al.*, 2014). This methylation process links creatine synthesis to one-carbon metabolism, highlighting the importance of methyl donor availability—particularly methionine—for optimal creatine production.

Dietary supplementation with GAA effectively bypasses the AGAT-dependent initial step of creatine synthesis, thereby reducing the metabolic demand for arginine (Portocarero *et al.*, 2021). This arginine-sparing effect is particularly relevant in broiler nutrition, as arginine is an essential amino acid in poultry and fulfills multiple physiological roles, including protein synthesis, nitric oxide production, and immune regulation (Fathima *et al.*, 2023). By reducing the utilization of arginine for endogenous creatine synthesis, a greater proportion of dietary arginine can be redirected toward growth-related processes and other vital physiological functions.

Once converted into creatine, GAA-derived creatine is distributed predominantly to skeletal muscle, where it is phosphorylated to phosphocreatine by the enzyme creatine kinase (Portocarero *et al.*, 2021). The phosphocreatine system functions as a rapid energy buffer, facilitating the regeneration of ATP from adenosine diphosphate (ADP) during periods of high and fluctuating energy demand (Kuznetsov *et al.*, 2025).

EFFECTS OF GAA ON GROWTH PERFORMANCE AND FEED EFFICIENCY

A substantial body of research demonstrates that dietary supplementation with GAA exerts positive effects on the growth performance of broiler chickens. (He *et al.*, 2020) reported that GAA supplementation at levels ranging from 600 to 1200 mg/kg significantly increased average daily gain (ADG) by 4.76 g and improved feed efficiency (gain-to-feed ratio, G:F) by 0.06 over a 42-day feeding period. Similarly, (Alaa *et al.*, 2024) showed that dietary inclusion of GAA at 0.6 g/kg significantly increased total body weight gain (BWG) by 91.28 g under low stocking density (LSD) conditions and by 77.47 g under high stocking density (HSD) conditions. In addition, FCR was improved by 0.05 in the LSD group and by 0.04 in the HSD group during a 35-day trial. These improvements were observed across different growth phases, indicating that GAA supports both early growth and later stages of muscle deposition.

Improvements in FCR are of particular economic importance, as feed costs represent the largest component of total production expenses in commercial broiler operations. Even relatively small reductions in FCR can translate into substantial feed savings when applied at a large production scale, thereby enhancing overall profitability. Consequently, GAA supplementation has attracted considerable attention as a nutritional strategy that improves not only biological efficiency but also the economic efficiency of broiler production.

The positive effects of GAA on growth performance are primarily attributed to its role in enhancing cellular energy availability through increased concentrations of creatine and phosphocreatine in muscle tissue. By improving the efficiency of ATP regeneration, GAA supports energy-demanding processes such as protein synthesis and muscle fiber development (DeGroot *et al.*, 2019). This improved energy status facilitates more efficient muscle accretion and directly contributes to increased body weight gain.

Beyond its effects on energy metabolism, GAA has also been reported to enhance the utilization of dietary nutrients, including amino acids and metabolizable energy (Cao *et al.*, 2024). The arginine-sparing effect induced by GAA allows arginine to be redirected from endogenous creatine synthesis toward growth-related functions, thereby improving overall nitrogen utilization. As a result, less nitrogen is lost through creatine metabolism, while a greater proportion is retained for protein synthesis and tissue accretion (Portocarero *et al.*, 2021).

Notably, the growth-promoting effects of GAA supplementation are often more pronounced in diets characterized by mild deficiencies in arginine or metabolizable energy. (DeGroot *et al.*, 2019) reported that in arginine-deficient starter and grower diets, supplementation with 0.12% GAA significantly increased final body weight, total body weight gain, and gain-to-feed ratio, with responses comparable to those observed in positive control diets supplemented with additional arginine (0.37% during the starter phase and 0.32% during the grower phase).

Under such nutritionally constrained conditions, GAA appears to compensate for metabolic limitations, highlighting its potential as a functional feed additive in cost-oriented feeding programs. Overall, these findings support the strategic use of GAA to enhance growth performance and feed efficiency in modern broiler production systems.

ARGININE SPARING EFFECT AND PROTEIN COST REDUCTION

Arginine is an essential amino acid in poultry nutrition and plays a critical role in protein synthesis, nitric oxide production, immune function, and overall growth performance (Sirathonpong *et al.*, 2019). Unlike mammals, poultry lack a fully functional urea cycle; therefore, their arginine requirement is entirely dependent on dietary intake. This physiological limitation makes arginine one of the most costly components in broiler feed formulation, particularly because feed amino acids constitute a high-value global market and their prices are strongly influenced by production costs and fermentation processes.

In addition to its physiological functions, arginine serves as a key substrate for endogenous creatine synthesis, a metabolic pathway that consumes substantial amounts of arginine (Nedeljkovic *et al.*, 2025). The initial step of creatine biosynthesis involves the transfer of an amidino group from arginine to glycine to form guanidinoacetic acid GAA (Joncquel-Chevalier Curt *et al.*, 2015). Dietary supplementation with GAA effectively bypasses this arginine-dependent step, thereby reducing the physiological demand for arginine in creatine production.

The arginine-sparing effect induced by GAA supplementation has important implications for feed formulation strategies. By decreasing the requirement for arginine in endogenous creatine synthesis, dietary arginine levels can be partially reduced without compromising growth performance or feed conversion efficiency, thereby improving nutrient utilization efficiency and lowering production costs (Sharma *et al.*, 2022).

Furthermore, the reduced arginine requirement creates opportunities to lower the crude protein content of the diet or decrease reliance on high-cost protein sources and synthetic amino acids. Diets formulated with lower crude protein levels not only reduce feed costs but may also decrease nitrogen excretion, thereby contributing to improved environmental sustainability in poultry production systems.

CARCASS TRAITS AND MEAT QUALITY

Beyond its well-documented effects on growth performance, dietary supplementation with GAA has also been shown to exert positive effects on broiler carcass and meat quality characteristics. In a study by (Zhao *et al.*, 2021), supplementation with 600 mg/kg GAA increased meat pH at 24 h postmortem to 5.98 and improved lightness (L*) to 48.16. In addition, drip loss was slightly reduced to 3.00% compared with 3.01% in the control group.

Improvements in breast muscle yield and meat quality are closely associated with the role of GAA in creatine metabolism and muscle energy homeostasis. Increased availability of creatine and phosphocreatine enhances the efficiency of ATP regeneration in muscle cells, thereby supporting sustained protein synthesis and muscle fiber hypertrophy (Kontos *et al.*, 2025). Consequently, GAA supplementation promotes more efficient muscle fiber development and lean tissue deposition without excessive fat accumulation.

Furthermore, the beneficial effects of GAA on water-holding capacity, reduced drip loss, and improved postmortem muscle tissue integrity are likely related to improved muscle energy status. A more favorable energy balance may delay postmortem glycolysis and reduce protein denaturation, thereby preserving muscle structure and functionality (Zhang *et al.*, 2019).

These improvements in meat quality have important economic implications for the poultry processing industry. Enhanced water-holding capacity and reduced drip loss contribute to higher processing yields, improved product appearance, and meat texture that is more desirable to consumers (Sun *et al.*, 2024). Moreover, these effects help minimize weight losses during storage, distribution, and further processing.

SAFETY, DOSAGE, AND PRACTICAL CONSIDERATIONS

GAA has been extensively evaluated for its safety in broiler nutrition, and substantial evidence indicates that this compound is safe when applied at recommended inclusion levels (Bampidis *et al.*, 2022; Bampidis *et al.*, 2022). The majority of studies report no adverse effects on health status, mortality rate, or organ function when GAA is supplemented at levels ranging from 0.06% to 0.12% in broiler diets (El-Faham *et al.*, 2019). Within this dosage range, GAA has consistently been shown to enhance performance without compromising animal welfare or physiological stability.

One critical aspect of GAA supplementation is the requirement for methylation to convert GAA into creatine (Ardalan *et al.*, 2020). This process depends on the availability of methyl group donors, such as methionine and choline, as well as other components of one-carbon metabolism (Speer *et al.*, 2022). Insufficient availability of methyl donors may limit the efficiency of GAA conversion to creatine and potentially increase metabolic burden due to excessive methyl group utilization. Therefore, diets containing GAA must be carefully formulated to ensure adequate methionine and choline supply, particularly in low-protein diets or cost-oriented feed formulations.

In addition to methyl donor balance, precise amino acid formulation is essential to maximize the benefits of GAA supplementation. Although GAA exerts an arginine-sparing effect, excessive reductions in dietary arginine or other essential amino acids may lead to suboptimal growth performance or metabolic imbalance (Portocarero *et al.*, 2021). Consequently, GAA should be incorporated into well-balanced diets rather than used as a substitute for sound nutritional principles. Precision formulation based on digestible amino acid requirements is strongly recommended to achieve optimal outcomes.

From a practical perspective, the effectiveness of GAA supplementation may be influenced by several factors, including broiler genotype, growth phase, dietary energy density, and overall management conditions (Çenesiz *et al.*, 2020). High-performing broiler strains and diets characterized by mild arginine or energy limitations generally exhibit more pronounced responses to GAA supplementation (DeGroot *et al.*, 2019). Therefore, farm-level evaluation and adjustment according to specific production conditions are essential to maximize the economic benefits of GAA use.

FUTURE PERSPECTIVES

Future research on GAA supplementation should increasingly focus on its interactions with key factors within modern broiler production systems. In particular, the interaction between GAA and dietary energy density warrants further investigation, as improvements in cellular energy metabolism may provide greater flexibility in energy formulation strategies without compromising growth performance or feed efficiency. Given the role of GAA in enhancing the creatine–phosphocreatine energy buffering system, its inclusion may allow for moderate reductions in dietary energy while maintaining optimal productive responses.

In addition, the potential synergistic effects between GAA and alternative protein sources, such as insect meal, fermented plant proteins, and agro-industrial by-products, represent a highly relevant research area. As the poultry industry seeks to reduce reliance on conventional protein sources such as soybean meal, understanding the role of GAA in supporting broiler performance when diets contain novel or lower-quality protein ingredients becomes increasingly critical. In this context, GAA may serve as a strategic nutritional tool to help sustain growth performance and nitrogen utilization efficiency.

Further studies are also required to evaluate the combined use of GAA with other functional feed additives, including enzymes, organic acids, probiotics, and antioxidants. Investigating these interactions may reveal additive or synergistic benefits that enhance nutrient utilization, gastrointestinal health, gut microbiota stability, and resilience to environmental stressors, such as heat stress or metabolic challenges. Such integrated approaches align with the principles of precision nutrition aimed at optimizing biological efficiency through complementary feed additive strategies.

From an economic perspective, more comprehensive cost–benefit analyses are needed across a range of commercial production systems. These evaluations should account for variability in feed ingredient prices, broiler genetics, management intensity, and market conditions. Integrating biological performance data with economic modeling will provide clearer guidance for producers and nutritionists in determining optimal, economically viable, and sustainable GAA supplementation strategies.

CONCLUSION

GAA is an effective feed additive that improves growth performance, feed efficiency, and overall productivity in broiler chickens by enhancing cellular energy metabolism. Its arginine-sparing effect also supports more efficient amino acid utilization, which may help reduce dietary protein requirements and feed costs. In addition, GAA contributes to better carcass traits and meat quality. However, its effectiveness depends on proper diet formulation, particularly adequate levels of methyl donors such as methionine and a balanced amino acid profile. Overall, GAA has strong potential to enhance both biological and economic efficiency in broiler production and can be a valuable component in sustainable and cost-effective feeding strategies.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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