Dietary Protein into Chicken-Meat Protein

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There is an urgent need to develop alternative dietary protein sources to partially replace soybean meal, which could range from meals based on black fly soldier larvae to enhanced canola meal in addition to reduced-CP diets. Moreover, a reduced demand for soybean meal by the chicken-meat industry would attenuate neo-tropical deforestation in South America. Synthetic and crystalline, or non-bound, amino acids were considered as alternatives to soybean meal, as reviewed by Selle et al.. These researchers contended that the chicken-meat industry's dependence on soybean meal would be halved if CP reductions of 50 g/kg are realised without compromised broiler growth performance. This would involve judicious dietary inclusions of non-bound amino acids to meet requirements.

amino acids broiler chickens glucose protein starch

1. Overview

The conversion of dietary protein and amino acids into chicken-meat is a dynamic and complex process. Dietary protein is transferred to protein in a chicken carcass at a conversion ratio in the order of 2.50:1, which leaves scope for improvement. Nevertheless, this conversion ratio in broiler chickens cannot be matched by other terrestrial food-producing animals. The quest for sustainable chicken-meat production would be greatly facilitated by enhancing the efficiency of this conversion. Therefore, this review explores the various pathways and processes involved with the objective of identifying approaches and strategies whereby the transition from dietary protein to chicken-meat protein can be advanced.

Viable alternatives to soybean meal would be advantageous but the increasing availability of non-bound amino acids is providing the opportunity to develop reduced-crude protein (CP) diets, to promote the sustainability of the chicken-meat industry and is the focus of this review. Digestion of protein and intestinal uptakes of amino acids is critical to broiler growth performance. However, the transition of amino acids across enterocytes of the gut mucosa is complicated by their entry into either anabolic or catabolic pathways, which reduces their post-enteral availability. Both amino acids and glucose are catabolised in enterocytes to meet the energy needs of the gut. Therefore, starch and protein digestive dynamics and the possible manipulation of this 'catabolic ratio' assume importance. Finally, net deposition of protein in skeletal muscle is governed by the synchronised availability of amino acids and glucose at sites of protein deposition. There is a real need for more fundamental and applied research targeting areas where our knowledge is lacking relative to other animal species to enhance the conversion of dietary protein and amino acids into chicken-meat protein.

2. Alternative Dietary Protein Sources

The conversion of dietary protein and amino acids into the protein of chicken-meat is indeed a dynamic process. Quite typically, broiler chickens attain a live weight of 2.918 kg at 42 days post-hatch and a carcass weight of 2.151 kg following processing. This translates to 376 g of carcass protein as a Ross 308 broiler carcass contains 175 g/kg protein [1]. Broiler chickens consume 4.702 kg of feed over 42 days with dietary protein contents declining from 230 to 183 g/kg, with a weighted average of 201 g/kg protein. This corresponds to an intake of 945 g protein for an output of 376 g. Therefore, 2.51 kg of dietary protein is required to generate 1.00 kg of protein in a chicken carcass or saleable end product. The dietary protein to carcass protein ratio of 2.51 is unmatched by other terrestrial food-producing animals. The efficiency of protein gain in broiler chickens (33.3%) was estimated to exceed that of pigs (23.3%) and feedlot cattle (12.1%) by clear margins [2]. Nevertheless, if reduced-crude protein (CP) diets could be developed so that a dietary reduction of 50 g/kg CP did not compromise growth performance, then the dietary protein to carcass protein ratio of 2.51 would decline to 1.89, a marked 24.7% improvement. The overall efficiency with which dietary amino acids are incorporated into chicken-meat, based on the data of He et al. [3], is in the order of 55%, but this may vary from 35% to 70% for a given amino acid. Thus, this review considers the transition from dietary protein and amino acids to carcass protein in broiler chickens with the intention of identifying strategies to enhance the complex, kinetic processes involved.

Soybean meal is the dominant source of dietary protein for chicken-meat production, supplying up to 70% of protein in a typical ‘corn-soy’ diet while the balance is derived from feed grains and feed-grade amino acids, usually lysine, methionine and threonine. While there are alternatives to soybean meal, the US chicken-meat industry utilised 15 million tonnes of soybean meal in 2017–2018, which is 48% of the total usage in that country [4]. Global production of soybean meal was 360 million tonnes in 2018/2019 [5] and chicken-meat production uses substantial amounts of this production. A decade ago, it was estimated that 11.4 million tonnes, or 32% of the total of 35.8 million tonnes, of soybean meal was fed to broiler chickens in the USA [6]. Global soybean production is forecast to increase from 369 million tonnes in 2020 to 407 million tonnes in 2027, and the price of soybeans is predicted to increase from USD 416 to USD 453 over the same timeframe [7]. The likelihood is that the price and supply situation of soybean meal will become an increasingly real challenge to sustainable chicken-meat production given the FAO projected robust growth in demand for chicken-meat to 2050 [8].

Consequently, there is an urgent need to develop alternative dietary protein sources to partially replace soybean meal, which could range from meals based on black fly soldier larvae [9] to enhanced canola meal [10] in addition to reduced-CP diets. Moreover, a reduced demand for soybean meal by the chicken-meat industry would attenuate neo-tropical deforestation in South America [11]. Synthetic and crystalline, or non-bound, amino acids were considered as alternatives to soybean meal, as reviewed by Selle et al. [12]. These researchers contended that the chicken-meat industry’s dependence on soybean meal would be halved if CP reductions of 50 g/kg are realised without compromised broiler growth performance. This would involve judicious dietary inclusions of non-bound amino acids to meet requirements. There are copious inclusions of non-bound amino acids in reduced-CP diets, thus the question is raised as to whether the bioequivalence of non-bound and protein-bound amino acids are identical. This appears unlikely given the different rates of intestinal uptakes between the two entities [13], which is addressed in this review. Finally, that broiler chickens achieve live weights of 3 kg in six weeks represents rapid growth rates and emphasises the need to consider the kinetics of dietary protein and amino acids transitioning to protein in chicken-meat, which is entwined with the digestive dynamics of starch and protein.

3. Conclusions

The sustainable production of broiler chickens in the future will stem largely from improvements in the efficiency of converting dietary proteins and amino acids into chicken-meat protein. These improvements could be generated by both selection programs and nutritional strategies. However, both approaches are thwarted by inadequacies in our knowledge of the relevant physiological and biochemical pathways in broiler chickens, which is obvious when compared to humans and other food-producing animal species. The development and adoption of reduced-CP broiler diets holds enormous promise for sustainable chicken-meat production and this opportunity has been central to this review. While the advantages that would flow from the adoption of viable reduced-CP broiler diets are irrefutable, the obstacles that stand in the way of their development are tangible. Vagaries in apparent amino acid digestibility coefficients and disappearance rates pursuant to reductions in dietary CP are in evidence, which complicate the formulation of reduced-CP diets based on ideal amino acid ratios. It is our contention that ideal amino acid ratios for a reduced-CP diet will differ from diets with standard CP concentrations. However, identification of ideal amino acid ratios for reduced-CP diets is a formidable challenge. Inclusion of feed grains increase in reduced-CP diets and the properties of starch in a given feed grain, including starch digestion rates, appear to hold importance. It has been shown that maize is a more suitable feed grain than wheat as the basis of reduced-CP diets. Somewhat ironically, the genesis of this advantage appears to be the lower protein content of maize and lower non-bound amino acid inclusions in maize-based, reduced-CP diets. A problematic issue is the bioequivalence of non-bound versus protein-bound amino acids where the likelihood is that they are not identical. Similarly, the metabolic fate of amino acids in their transition across enterocytes of the gut mucosa and their interactions with alternative energy substrates, especially glucose, is an area which requires clarification in poultry. Another issue is whether or not the conversion of essential amino acids to non-essential amino acids occurs at sufficiently rapid rates in broiler chickens to meet requirements and emphasise the importance of the many functional roles played by amino acids, over and above protein accretion. The all-important differential between protein synthesis and protein degradation, or net protein synthesis, in skeletal muscle of broiler chickens demands further investigation. Concentrations of free amino acids in portal and/or systemic plasma should provide insights into the post-enteral availability of amino acids, but interpretation of this data is not straightforward as it reflects a complex and kinetic position. The metabolism of protein and energy in broiler chickens is inextricably linked, where protein synthesis is just one example, and we need to advance our comprehension of both factors in tandem. Indeed, it is our contention that a better appreciation of starch and protein digestive dynamics in broiler chickens is a necessity if progress is to be achieved in the development of reduced-CP diets. In this respect, free threonine concentrations in systemic plasma may be indicative. Finally, more fundamental and applied research targeting areas where our knowledge is lacking needs to be completed if the objective of sustainable chicken-meat production via reduced-CP diets is to be realised.

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