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Effect of L-Threonine supplementation on broiler chicken: A review

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Abstract
The global poultry industry is facing severe economic pressure due to high prices of feed ingredients. High soya prices make alternative ingredients more attractive. However, their availability is limited. When partially replacing soya bean meal, DGGS and rape seed meal, both by-products of the biofuel industry are of particular interest. However, their protein digestibility is lower compared to soya and can be more variable. Therefore, all formulations with alternative ingredients must be based on digestible amino acids. Amino acids (AA) are important in poultry nutrition not only for protein deposition, but also for other metabolic functions; such as improving immune and gut function. Recent advances have been made in developing industrial process for economical production of synthetic amino acids. L-Lysine, DL-Methionine, L-Threonine and L-Tryptophan, L-Valine in commercial poultry birds to reduce the feed cost. This has resulted in poultry Nutritionists reducing the crude protein levels while maintaining the bird performance and profitability. This review examines broiler literature on L-Threonine and makes extrapolations relating to commercial conditions. Further functions of L-Threonine in metabolism and threonine content of feedstuffs are discussed.

Keywords: Amino acid, broiler, low crude protein, Threonine

Introduction

High crude protein (CP) diets for broiler chickens results in amino acid excess and elevated nitrogen excretion. Nitrogen retention efficiency may be increased if low CP broiler diets are supplemented with crystalline amino acids in a pattern that matches maintenance and tissue accretion needs. Nevertheless, the inclusion of synthetic methionine and crystalline L-lysine has resulted in commercial diets being formulated for crude protein levels well below NRC recommendations [1]. The availability of L-threonine as a feed additive may allow poultry nutritionists, specifically turkey nutritionists, to further decrease dietary crude protein. Reducing dietary crude protein will: 1) improve nitrogen efficiency utilization; 2) reduce nitrogen excretion; 3) improve poultry tolerance of high ambient temperatures; and 4) reduce the level of ammonia in litter. However, as dietary crude protein decreases, the amino acid composition of the diet should match the bird's amino acid requirements for maintenance and tissue accretion in order to obtain optimum performance. Adequate L-threonine levels are needed to support optimum growth because it serves as an important component of body protein and plays important role as precursor of L-lysine and serine and additionally for optimum immune response and gastrointestinal mucin production.

W. C. Rose discovered threonine in 1935.Shortly after this discovery, threonine was deemed an essential amino acid for chicks [2, 3]. In most plant based feedstuff for poultry, threonine is the third limiting amino acid in corn soybean rations for broiler chickens and it becomes more limiting as CP decreases [4] and is one of the major factors in limiting the bird performance as inclusion of crystalline L-lysine and DL-methionine in complete diets have increased. Since these and other early investigations of threonine in poultry, the 1980's and 90's have given rise to numerous threonine studies evaluating threonine requirements, threonine's efficacy in low protein diets, and enzymatic pathways responsible for threonine catabolism. Threonine is the third limiting amino acid in low crude protein diets for poultry. As techniques in fermentation of threonine-producing microorganisms improve, the commercial availability of L-threonine should increase. This review seeks to evaluate our current knowledge of L-threonine and provide insight on its future commercial application in the poultry industry.

Threonine Metabolism

Generally Amino acid metabolism involves: 1) protein synthesis and degradation, 2) incorporation of amino acid nitrogen into uric acid, 3) conversion of amino acid carbon skeletons into glucose, fat, energy, or C02 and H20, and 4) formation of non-protein derivatives. Threonine participates in protein synthesis, and its catabolism generates many products important in metabolism *(i. e.* glycine, acetyl-CoA, and pyruvate). Poultry are not capable of synthesizing threonine de *novo* which makes it a nutritionally essential amino acid. Threonine (2-amino-3-hydroxybutyric acid, QH9N03) has a molecular weight of 119.12 and contains 11.76% nitrogen.

Catabolism of L-threonine results largely in glucogenic products because it yields both pyruvate and propionate Threonine dehydratase, threonine dehydrogenase and threonine aldolase participate in threonine catabolism in chicks. However, threonine dehydrogenase accounts for most of the threonine oxidation in mammals in the fed state [5, 6]. threonine generate pyruvate for energy or glucose production and glycine for metabolic needs *(e. g.* synthesis of protein, creatine, serine, uric acid, bile salts, and glutathione).Chicks require glycine or serine [7, 8]. Baker *et al.* [9] evaluated the sparing effect of threonine on glycine by feeding chicks a completely purified glycine-free diet. These authors demonstrated that excess supplemental levels of dietary threonine (1.3%) heightened growth in chicks fed a glycine- and serine-free diet. When glycine was added to the high threonine diet, chick growth was decreased but gain: feed was improved. Thus, the glycine requirement of chicks can be partially spared by additional threonine; the reverse pathway (glycine to threonine), however, does not occur in chicks. Conversely, D'Mello [10] found that threonine does not spare glycine in the chick. Threonine's ability to spare glycine in chicks remains subject to conjecture.

Threonine Content of Feedstuffs

Threonine is the third limiting amino acid in corn-soybean meal poultry rations [11]. Diets composed mainly of corn and soybean meal are not limiting in threonine. Threonine, like lysine, is limiting in most cereals. Wheat, wheat midds, sorghum (milo), barley, and meat and bone meals are low in threonine, and their use may cause threonine to be a pressure point in poultry rations. Crystalline L-threonine may allow flexibility in diet formulation to utilize alternate ingredients.

Digestible amino acid values are not compared within this review; however, feed formulation practices utilizing true ileal digestibility values have clear advantages. Benefits from formulating on a digestible amino acid basis include: 1) amino acids being provided closer to the birds' true requirement; and 2) formulation practices that are more flexible and allow inclusion of more alternate ingredients. Moreover, formulating on a digestible amino acid basis and utilizing alternate ingredients and crystalline amino acids may become economically advantageous.

Threonine Research in Broilers

Recently, threonine is considered as the third or fourth limiting amino acid in most feedstuffs of plant sources for poultry. It is also considered as one of the important factors that affect poultry performance due to increase in the use of lysine and methionine in broilers diet (Gong *et al*. 2005) The threonine requirement for young broilers has been studied extensively in the past decade. During this time, estimates of threonine requirements in young male and female broilers ranged from 0.68 to 0.79% and 0.58 to 0.75% of the diet, respectively. Prior to 1990 not much work was done on defining threonine dose response curves, however, since then various researchers have published threonine requirements for broiler chickens, (Baker *et al*. 1994; Kidd *et al*. 1996; Webel *et al*. 1996; Barkley and Wallis, 2001; Baker *et al*. 2002). In all of these trials use was made of the graded supplementation (additive) technique to measure the response to threonine.

Kidd *et al*. [17] conducted two studies evaluating threonine responses in low crude protein diets utilizing threonine limiting ingredients. Experiment 1 evaluated graded levels of threonine (92 to 112% of the NRC) in milo, soybean meal, wheat, and meat and bone meal based diets from 1 to 56 days of age. A linear improvement in feed conversion was observed from 1 to 42 days of age. This suggests that threonine may become more important in older birds possibly because of a higher maintenance requirement. Studies have shown that low protein diets result in optimal feed conversions in broilers [18-23]. Other research, however, has demonstrated that low crude protein diets do not result in optimal feed conversions [24-27]. It is well known that low crude protein diets improve protein utilization by minimizing excesses of essential amino acids [28, 29]. If reducing the crude protein content of the diet is favored, threonine's importance may depend on the extent to which crude protein is reduced.

Chicks' threonine requirement is variable ideal protein concept may minimize variability in threonine requirements, and all other essential amino acid requirements, by setting specific ratios of amino acids to lysine [30]. Exact amino acid requirements for many amino acids, especially in later growth of poultry, are not known. Thus, the ideal protein concept provides a basis for nutritionists to formulate diets to meet amino acid needs. Because the ideal protein concept has the potential to be an instrumental tool for linear programming for poultry nutritionists, specific ratios in the older bird for all amino acids should be validated experimentally.

Digestible Threonine Requirements and dThr/dLys Ideal Ratio Recommendations

Reference	Strain	Sex	Age	Parameter1	dThr (%)	dThr/dLys	Method	Comment
Mehri *et al*. (2012)	Ross308	M	3-16d	BWG FCR	0.78 0.75	70 66	CCRD	
Star *et al*. (2012)	Ross308	M	9-20d	G/F	0.69	68	LBL	
Corzo *et al*. (2009)	Ross TP16	M	14-28d	BWG FCR	0.68	69 70	LBL	
Everett *et al*. (2010)	Ross TP16	M	28-42d	General	0.73 0.76	68		
Mejia *et al*. (2012)	Ross708	M	35-49d	BWG FCR BMW	0.72 0.72 0.75	66 66 68	QBL	
Kidd (1999)	Ross x Hubbard	M	42-56d	Growthy Carcass	0.72 0.72		95% of Qmax	
Dozier *et al.* (2010)	Ross308	M	42-56d	BWG FCR CY BMW	0.68 0.67 0.75 0.70			

Impacts of Dietary L-Threonine Supplementation on Performance, Immunity and Intestinal Morphology of Broiler Chickens

Adequate L-threonine levels are needed to support optimum growth because it serves as an important component of body protein and plays important role as precursor of L-lysine and serine and additionally for optimum immune response and gastrointestinal mucin production (Kidd MT *et al*. 1999). K. Shirzadegan *et al*. 2015 indicate that 0.75% L-threonine in diet could improves the intestinal morphology and consequently BWG of broilers under hot and humid status, but don't has any significant effect on carcass traits. Furthermore, although the higher dietary L-threonine (1%) similar to 0.75% increased the villi height in jejunum and ileum, but did not change the performance of broilers. Star *et al*. (2010) investigated threonine requirement of broilers during sub-clinical intestinal clostridium infection. Coccidioses and Clostridium perfringens infections can cause intestinal damage and increase mucus production. In this study, threonine re quirements were assessed in response to Thr: Lys ratio (0.65 vs. 0.70 SID) in two situations: challenged or nonchallenged with Eimeria maxima and Clostridium perfringens in a sub-clinical Clostridium infection model. Rezeipour *et al*. (2012) exhibited that supplementation of threonine to broiler diets improve feed efficiency, weight gain and intestinal morphology by increasing crypt depth and villi height and width of ileum and jejunum. Authors also, observed that addition of threonine to broiler diets increases antibody titer against Newcastle disease at 42 day of age. Findings of Maroufyan *et al*. (2010) are in line with those mentioned above. Researchers noticed that use of methionine and threonine in broiler diets above NRC recommendations considered as a better nutritional strategy to overcome unfavorable stress conditions by improving immune cells in tropical area. In addition, Moghaddam and Emadi, (2014) assured these findings, authors concluded that dietary threonine and vitamin A improve broilers immune response. Corzo *et al*. (2007) attributed increase in threonine requirements for broilers raised in built-up litter environments to microbial challenges, because threonine involved in mucin formation and mucin control microbial communities and nutrient availability in the gut. Manegar *et al*. (2017) indicated that with supplementation of L-threonine, the dietary CP can be reduced by 1.5 per cent units without affecting BWG and FI, and by 0.75 per cent unit without affecting feed conversion ratio in commercial broilers. Estalkhzir *et al*. found that the addition of threonine to broiler chicken diets increased productivity in terms of Body Weight (BW), Feed Conversion (FC), Dressing Percentage (DP), relative breast weight (BRp) and thigh weight (THp). In addition, Rezaeipour *et al*. reported that threonine supplementation together with feed particle size improved FC, whereas threonine supplementation for the first 42 days after birth improved FC to levels above those seen with the addition of probiotics

Conclusion

Threonine is typically the third limiting amino acid in corn and soybean meal diets for broilers. In practice, threonine may become a pressure point in linear programming with implementation of high dietary levels of threonine-limiting ingredients, particularly wheat, milo, barley, and meat and bone meals. Dietary supplementation of L-threonine, along with synthetic methionine and L-lysine, may allow nutritionists to further reduce the inclusion of protein rich feedstuffs while maintaining bird performance. L-Thr supplementation can improve immunity, antioxidant capacity, and intestinal health of broilers at an early age. Threonine is the third limiting amino acid in commercial poultry diets needed for protein accretion particularly for optimatization of breast meat yield. Threonine has a significant impact on development of gastrointestinal tract, production. of mucin and gut immune system. Threonine requirement of poultry is higher in unclean or stress conditions. Supplementation of threonine above the recommendation levels in the poultry diets is beneficial to achieve optimum performance and production under commercial rearing conditions.

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