Arginine: The most versatile amino acid

Heinrich Jansen van Vuuren[1*]
[1] Chemuniqué Pty Ltd, 28 Eagle Lane, Lanseria Business Park, Lanseria, 1739, South Africa
*Corresponding author

Abstract

In terms of commercial availability, arginine is relatively new to the amino acid market. However, arginine is arguably one of the most versatile amino acids in terms of metabolic importance. Through its various metabolites, arginine is involved in almost all metabolic functions. An increase in dietary arginine has been shown to increase various immunological parameters, while maintaining adequate growth. Additionally, birds may profit from an arginine-to-lysine ratio above the classical breeder recommendations. With the current available knowledge, the targeted application of arginine to achieve specific nutritional, performance or health goals seems to be distinctly possible.

Background

The increased availability of crystalline essential amino acids has made it possible to reduce crude protein (CP) while maintaining performance and profitability. Environmental and welfare considerations for both livestock and humans have contributed to the drive to reduce the use of antibiotic growth promoters (AGP) (Lui et al., 2019), which in turn have created new challenges for nutritionists and opened new research avenues over the past decade. The reduction in AGP in feed have led to challenges in maintaining gut health (Danzeisen et al., 2011; Bao, 2020). While reducing CP levels has contributed to managing gut health in the post-AGP era, the extent to which CP can be lowered successfully has been limited due to the economic feasibility of including lower-tiered limiting essential amino acids (EAA). In the past decade however, most EAA have become commercially available at a reasonable cost.

In terms of commercial availability, arginine is relatively new to the amino acid market. It is considered to be either the fourth- or fifth-limiting amino acid in poultry, but only seventh in swine, depending on various nutritional, climatological, and immunological factors (Abdulkarimi, 2019; Castro, 2020). Arginine performs multiple functions in the body and is either directly or indirectly involved in several metabolic processes through its many biologically important metabolites. Arginine, which serves as the parent molecule of guanidinoacetic acid (GAA; also known as glycocyamine or guanidinoacetate), ornithine, polyamines, proline, glutamate, and nitric oxide (NO), which have been shown to be important in the maintenance of the immune system and circulatory functions (Fouad et al., 2012).

Arginine and immunity

Improved immunity is where arginine can make a much-needed contribution. An increase in dietary arginine has been shown to increase the heterophil-to-lymphocyte ratio in broilers challenged with infectious bronchitis virus (IBV), as well as increase the number of CD8+ cells, while maintaining adequate growth (Lee et al., 2002). Birds vaccinated and exposed to hydropericardium syndrome virus (HSPV) and supplemented with arginine showed increased humoral and cell-mediated immune (CMI) responses to the HSPV challenge, as well as increased bursa and spleen weights, relative to body weight (Munir et al., 2009). This corresponds to an earlier study by Kwak et al. (1999) that reported reduced lymphoid organ weights (thymus, spleen, and bursa) relative to body weight when birds were fed an arginine-deficient diet. Tayade (2006) reported that arginine supplementation stimulated intestinal intraepithelial lymphocytes as well as CMI responses after vaccination against infectious bursal disease (IBD), thereby enhancing the effectiveness of the vaccine – from 80% to 100% in this specific study. Arginine supplementation was shown to be effective in preventing necrotic enteritis by attenuating the inflammatory response and reversing intestinal malabsorption-induced by Clostridium perfringens (Zhang et al., 2019). Supplementary arginine was shown to be a powerful immune stimulant that may increase the effectiveness of vaccines (Tayade et al., 2006). Ospina-Rojas et al. (2019) suggested that higher arginine supplementation may play a role in improving carcass quality though improved skin strength and reduced skin infections and lesions. Corzo (2003) reported a linear reduction in infected skin lesions, bone fractures, and dislocated joints with higher levels of supplemented arginine; however, these results were achieved in older birds. Although arginine and its metabolites are important in wound healing and cartilage formation, more research is needed to investigate the potential of arginine to improve carcass quality.

Arginine and metabolic disorders

In a 1995 study, Wideman et al. found that the mortality rate due to cold-induced ascites was reduced when arginine was supplemented to cold-stressed broilers. Increasing arginine supplementation also reduced right ventricular hypertrophy, probably due to higher NO levels reducing pulmonary arterial pressure (Wideman et al., 1995). Similar results were reported by Khajali et al. (2013) when arginine supplementation was administered to broilers at high altitude. Increased plasma NO, lower hematocrit values, and a lower right ventrical to total ventrical ratio was observed.

Optimal requirements

Optimal standardized ileal digestible (SID) requirements for arginine, expressed in relation to lysine (SID Arg:SID Lys) reported in literature varies from 105 to 125, depending on the parameter measured, with an average of 114–115 during the starter and grower phases, respectively (Ospina-Rojas et al., 2019). The highest SID Arg:SID Lys required is for optimal immune function (>125; Corzo et al., 2003), followed by feed conversion ratio or FCR (114; Corzo, 2012) and maximum body weight (BW) gain (106; Corzo, 2012). Higher levels may be needed for increased skin and joint strength, perhaps as high or even higher than 122 (Jahanian, 2009) to 125 (Corzo et al., 2003). In the most recent study by Corzo et al. (2020), optimal SID Arg:SID Lys ratios were reported as 105 for BW gain and 108 for FCR in birds younger than 25 days. However, the requirements increased with age and the optimal ratios for BW gain and FCR from 25–42 days were 129 and 116, respectively. The same study reported requirements for carcass yield, breast weight, and breast yield as 136, 112 and 109, respectively, while thigh weights increased linearly with increasing arginine supplementation.

Conclusions

Arginine is arguably one of the most versatile amino acids in terms of metabolic importance. Through its various metabolites, arginine is involved in almost all metabolic functions. Optimizing arginine supplementation beyond least-cost formulations in modern vegetable-based diets creates new opportunities for the nutritional management of various challenges in broiler production. Depending on the specific variable in question, different SID Arg:SID Lys ratios should be used to reach optimal performance. With the current available knowledge, the targeted application of arginine to achieve specific nutritional, performance or health goals seems to be distinctly possible.

Acknowledgement

First published in AFMA Matrix, January 2022.

REFERENCES

1. Abdulkarimi, R., Shahir, M.H., and Daneshyar, M. 2019. Effects of dietary glutamine and arginine supplementation on performance, intestinal morphology and ascites mortality in broiler chickens reared under cold environment. Asian-Australas J Anim Sci Vol. 32, No. 1:110-117.
2. Bao, Y. 2020. Amino acid nutrition and chicken gut health. World's Poultry Science Journal, DOI:10.1080/00439339.2020.1759387.
3. Castro, F.L.S., Teng, P., Yadav, S., Gould, R.L., Steven Craig, S., Pazdro, R., and Kim, W.K. 2020. The effects of L-Arginine supplementation on growth performance and intestinal health of broiler chickens challenged with Eimeria spp. Poultry Science 99:5844–5857.
4. Corzo, A. Determination of the arginine, tryptophan, and glycine ideal-protein ratios in high-yield broiler chicks. J. Appl. Poult. Res. 21 :79–87.
5. Corzo, A., Lee, J., Vargas, J.I., Silva, M., and W. J. Pacheco, W.J. 2020. Determination of the optimal digestible arginine to lysine ratio in Ross 708 male broilers. J. Appl. Poult. Res. 30:100136.
6. Corzo, A., Moran, E.T., Jr., and Hoehler, D. 2003. Arginine Need of Heavy Broiler Males: Applying the Ideal Protein Concept. Poultry Science 82:402–407.
7. Danzeisen, J.L., Kim, H.B., Isaacson, R.E., Tu, Z.J., and Johnson, T.J. 2011. Modulations of the chicken cecal microbiome and metagenome in response to anticoccidial and growth promoter treatment. PLoS ONE 6(11): e27949.
8. Fouad, A.M., El-Senousey, H.K., Jang, X.J., and Yao, J.H. 2012. Role of dietary L-arginine in poultry production. Int. J. Poult. Sci. 11(11): 718-729.
9. Jahanian, R. 2009. Immunological responses as affected by dietary protein and arginine concentrations in starting broiler chicks. Poultry Science 88 :1818–1824.
10. Khajali, F., Basoo, H., and Faraji, M. 2013. Estimation of arginine requirements for male broilers grown at high altitude from one to twenty-one days of age. J. Agr. Sci. Tech. Vol. 15: 911-917.
11. Kwak, H., Austic, R.E., and Dietert, R.R. 1999. Influence of dietary arginine concentration on lymphoid organ growth in chickens. Poultry Science 78:1536–1541.
12. Lee, J.E., Austic, R.E., Naqi, S.A., Golemboski, K.A., and Dietert, R.R. 2002. Dietary arginine intake alters avian leukocyte population distribution during infectious bronchitis challenge. Poultry Science 81:793–798.
13. Liu, S., Tan, J., Hu, Y., Jia, X., Kogut, M.H., Yuan, J., and Zhang, H. 2019. Dietary l-arginine supplementation influences growth performance and B-cell secretion of immunoglobulin in broiler chickens. J Anim Physiol Anim Nutr. 103: 1125–1134.
14. Munir, K., Muneer, M.A., Masaoud, E., Tiwari, A., Mahmud, A., Chaudry, R.M. and Rashid, A. 2009. Dietary arginine stimulates humoral and cell-mediated immunity in chickens vaccinated and challenged against hydropericardium syndrome virus. Poultry Science 88 :1629–1638.
15. Ospina-Rojas, I.C., Rodrigueiro, R.J.B., and Otani, L. 2019. Optimal dietary arginine levels in modern broiler chickens. Engormix, https://en.engormix.com/poultry-industry/articles/optimal-dietary-arginine-levels-t43741.html.
16. Tayade, C, Koti, M., and Mishra, S.C. 2006. L-Arginine stimulates intestinal intraepithelial lymphocyte functions and immune response in chickens orally immunized with live intermediate plus strain of infectious bursal disease vaccine. Vaccine 24: 5473–5480.
17. Wideman, R.F., Jr., Kirby, Y.K., Ismail, M., Bottje, W.G., Moore, W.M., and Vardeman, R.C. 1995. Supplemental L-arginine attenuates pulmonary hypertension syndrome (ascites) in Broilers. Poultry Science 74:323-330.
18. Zhang, B., Gan, L., Shahid, M.S., Lv, Z., Fan, H., Liu, D., and Guo, Y. 2019. In vivo and in vitro protective effect of arginine against intestinal inflammatory response induced by Clostridium perfringens in broiler chickens. Journal of Animal Science and Biotechnology, 10:73-84.