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Nutrition and Coccidiosis

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Introduction

Coccidiosis is the most common parasitic disease caused by Eimeria spp., leading to over $14 billion economic loss worldwide annually (Blake et al., 2020). The most prevalent Eimeria spp. in poultry include *E. tenella, E. maxima, E. acervulina, E. brunetti, E. necatrix, E. praecox, and E. mitis* and have different level of pathogenicity and specific infection sites in the intestine (Cervantes et al., 2020). Eimeria spp. invade intestinal epithelial tissues and induce intestinal damage, causing inflammation, oxidative stress, hemorrhage, and diarrhea. Furthermore, coccidiosis causes reduction of growth performance, intestinal integrity, nutrient digestibility, and increase of mortality and mobility in poultry.

Nutrition strategies have been evaluated to mitigate detrimental impact of coccidiosis in poultry. Prebiotics, probiotics, enzymes, antioxidants, amino acids, vitamins and minerals have shown to reduce severity of intestinal damage and stimulate nutrient digestion and fast recovery of the intestinal damage and growth performance (Parker et al., 2007; Amerah and Ravindran, 2015; Bortoluzzi et al., 2018; Oxford and Selvaraj, 2019; Souza et al., 2020; Yadav et al., 2020; Castro et al., 2020ab; Teng et al., 2020a). In order to develop efficient nutrition strategies, understanding of Eimeria infection on gut health and nutrient digestibility is critical. Thus, this paper will discuss about 1) Eimeria infection on gut health; 2) Eimeria infection on nutrient digestibility; and 3) Roles of key amino acids in Eimeria challenged broilers.

Eimeria infection on gut health

Eimeria infection increases intestinal damage, lesion score, gut permeability, inflammation, and oxidative stress, and such detrimental effects are highly correlated with

Eimeria oocytes ingested by chickens (Adedokun and Adeola, 2016; Rochell et al., 2016; Zhang et al., 2017; Sakkas et al., 2018; Teng et al., 2020b, 2021). Recently, Teng et al. (2020b) evaluated graded levels of mixed Eimeria challenge (*E. maxima, E. tenella, and E. acervulina*) on growth performance and gut health (gut permeability, intestinal morphology, lesion score, and intestinal tight-junction protein expression) in broilers. The authors found that increase of Eimeria challenge dose linearly reduced feed intake and body weight gain, and intestinal villi height (Fig. 1), whereas it increased lesion score and upregulated key tight junction proteins, claudin 1 and Jam2. Moreover, gut permeability linearly increased on 5-, 6-, and 7-days post-infection (dpi) when Eimeria oocysts challenge dose increased. However, the gut permeability was back to the normal on 9 dpi. The results indicate that Eimeria infection causes detrimental effects on growth performance and gut health.

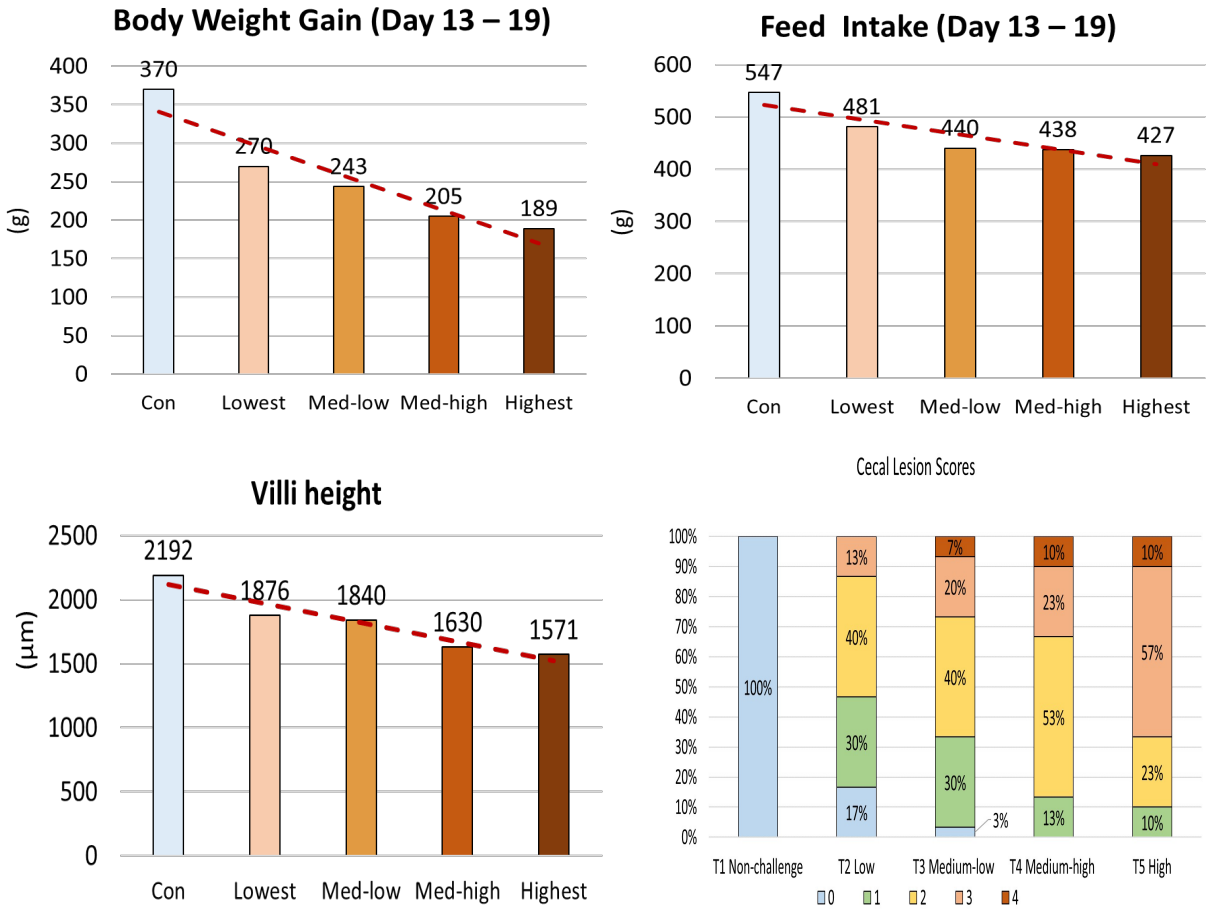

Figure 1. Effects of graded Eimeria challenge on growth performance and lesion score (Teng et al., 2020b).

Eimeria infection on nutrient digestibility

Several studies have shown that Eimeria infection reduces nutrient digestibility (Persia et al., 2006; Sakkas et al., 2018; Rochell et al., 2016; Teng et al., 2020b, 2021). Rochell et al (2016) reported that the apparent ileal digestibility (AID) of amino acids, except tryptophan and glycine, was linearly reduced in response to graded *E. acervulina* challenge. A study by Teng et al. (2020b) showed that increased mixed Eimeria spp. infection linearly decreased AID of digestible energy (Fig. 2) and minerals, such as sodium, potassium, calcium, magnesium, and phosphorus. These results clearly show that Eimeria infection reduces nutrient digestion and absorption in broilers, resulting in growth performance loss.

The reduction of nutrient digestibility caused by Eimeria infection may be due to reduction of digestive enzyme secretion and nutrient transports expression in the intestine. It has been reported that the activity and expression of several key mucosal brush border enzymes, such as maltase, sucrose, aminopeptidase, sucrose isomaltase, and alkaline phosphatase, were considerably limited by Eimeria infection in the intestine of broilers (Adams et al., 1996; Paris and Wong, 2013; Su et al., 2015). In addition, Eimeria infection significantly inhibits the expression of nutrient transporters in the intestine (Su et al., 2014, 2015; Teng et al., 2021). *E. acervulina and E. maxima* reduced the expression of glucose transporters as well as amino acid transporters including neutral amino acid transporters, cationic amino acid transporters, and excitatory amino acid transporters in the intestine of broilers (Su et al., 2015). Teng et al. (2021) also reported that graded *E. maxima* infection linearly regulated glucose and amino acid transporters in the brush boarder and basolateral member of the intestine.

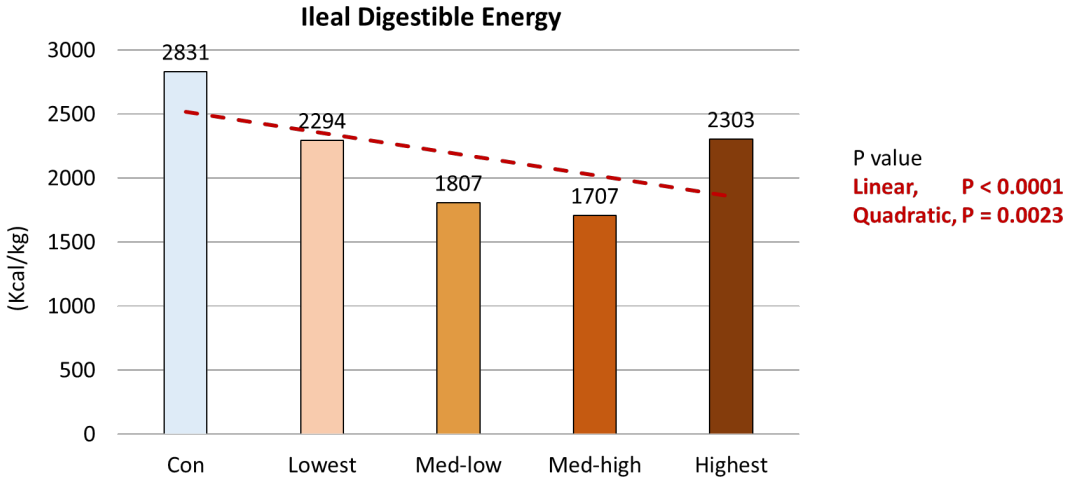

Figure 2. Effects of graded Eimeria challenge on ileal digestible energy (Teng et al., 2020b).

Roles of key amino acids in Eimeria challenged broilers

It has been reported that specific amino acids exhibit beneficial effects on intestinal development, immunity, gut integrity and anti-oxidant defense system in broilers challenged with Eimeria spp. (Gottardo et al., 2016; Zhang et al., 2017; Bortoluzzi et al., 2018; Castro et al. 2020ab). Among key amino acids, the functional effects of methionine, threonine, glutamine, and arginine have gained attention to alleviate detrimental effects of Eimeria infection in broilers.

Methionine is the first limiting amino acid in corn and soybean-based diets for poultry and plays important roles in metabolic functions, including methyl group donors, sulfur donors, and formations of cysteine, glutathione (GSH), taurine, carnitine, and polyamine (Stipanuk, 2004; Bunchasak, 2009). Because Eimeria infection reduces methionine digestibility and increases oxidative stress and inflammation in the body (Persia et al., 2006; Rusell et al., 2016; Souza et al., 2020; Yadav et al., 2020; Teng et al., 2021), methionine supplementation may improve anti-oxidant defense via GSH and reduce oxidative stress. Chen et al. (2013) reported that methionine supplementation increased serum SOD activity and total antioxidant potential in broilers and turkeys (Chen et al., 2013; Jankowski et al., 2017). Castro et al. (2020a) found that methionine supplementation increased GSH in the liver of broilers infected with three Eimeria spp. (*E. acervuline, E. tenella, and E. maxima*), alleviating oxidative stress caused by Eimeria inflation.

Threonine is the third limiting amino acid and the major component of mucin in the intestine (Corzo et al., 2007; Faureet al., 2002). Because Eimeria infection causes intestinal damage and increases mucin production in the intestine, threonine is one of the important amino acids to maintain intestinal integrity and rapid recovery during and after Eimeria infection. Zhang et al (2017) reported that threonine deficiency significantly increased Eimeria oocysts shedding and gut leakage in 25X Eimeria vaccine challenged broilers, and increased supplementation of threonine from 0.48 to 0.96% improved intestinal integrity and reduced oocyst shedding. Kidd et al. (2003) also reported that increased threonine supplementation from 0.6 to 0.8% enhanced growth responses (body weight gain, feed intake, and feed conversion ratio) in broilers, regardless of mid-*E. acervulina* challenge (30,000 oocysts). Recently, Teng et al. (2021) found that 0.75% threonine supplementation in a low protein diet increased villus

height and JAM2, a tight junction protein, in broilers challenged with mixed Eimeria spp. (*E. acervulina, E. maxima,* and *E. tenella*), suggesting that threonine supplementation can be a nutritional strategy to improve gut health in broilers under coccidiosis condition. Moreover, threonine is a critical amino acid regulating immunoglobin production and inflammatory responses. Increasing dietary threonine enhanced IgA secretion and reduce pro-inflammatory cytokines such as INF-γ and IL-1 β (Chen el al., 2017).

Glutamine is an important fuel source of enterocytes during cell proliferation and repairment particularly during inflammation, oxidative stress and challenge conditions and a key component of glutathione that plays an essential role in body antioxidant system (Rao and Samak, 2012; Bortoluzzi et al., 2018). It has been reported that dietary supplementation of glutamine improved growth performance and gut health in broilers (Yi et al., 2005; Waldroup et al., 2012; Luquetti et al., 2016; Oxford and Selvaraj, 2019). Yi et al. (2005) reported that 1% glutamine supplementation improved growth performance and intestinal development in broilers challenged with 40,000 oocysts of *E. maxima*. Oxford and Selvaraj (2019) also found that 1% glutamine supplementation increased villus height and villus height to crypt depth ratio and the gene expression of tight junction proteins, whereas there was no difference in growth performance among the treatments. Recently, Teng et al. (2021) reported that 0.75% glutamine supplementation in a low protein diet reversed detrimental effects of Eimeria infection on tight junction protein expression in broilers.

Arginine is an essential amino acid for poultry and has beneficial effects on body composition (fat, muscle, and bone metabolisms), oxidative stress, immunity, and gut health in poultry. Besides the muscle protein synthesis, arginine is an essential precursor of many key molecules in the body such as glutamate, glutamine, creatine, nitric oxide, proline, and polyamines (Ball et al., 2007; Khajali and Wideman, 2010; Castro et al., 2019). Moreover, arginine plays an important role in growth hormone (GH) secretion and consequently increases insulin-like growth factor (IGF-1), which regulates muscle accretion and bone development (Liu and LeRoith,1999; Corzo et al., 2003; Silva et al., 2012). In addition, it was reported that an abdominal fat deposition was limited in broilers fed additional arginine supplemented diet (Fouad et al., 2013). Dietary supplementation of arginine improved total body antioxidant capacity and increased key antioxidant system in the body, including glutathione and superoxide dismutase (Atakisi et al., 2009; Duan et al., 2015).

Eimeria infection significantly affects arginine metabolism in broilers; *E. acervulina* infection reduced plasma arginine and increased nitrogen oxide production via arginine degradation (Allen and Fetterer, 2000; Rochell et al., 2016). Arginine supplementation reduced oocysts shedding of Eimeria spp. (Allen 1999; Laika and Jahanian, 2017), suggesting that arginine may directly and indirectly influences Eimeria life cycle. Recently Teng et al. (2021) reported that dietary arginine supplementation in broilers fed a low protein diet significantly reduced gut permeability, indicating that arginine supplementation can be a nutritional strategy to improve gut health under coccidiosis condition. Castro et al. (2020b) evaluated the effect of different levels of arginine (1.04, 1.14, 1.24, 1.34, and 1.44%) on growth performance and gut health of broilers challenged with mixed Eimeria spp. Eimeria challenge adversely affected growth performance, intestinal integrity, and nutrient digestibility in broilers. The birds fed 1.44% arginine had significantly higher body weight gain compared to those fed 1.04%, and 1.34% arginine fed birds showed lower feed conversion ratio compared to those fed 1.04%. Moreover, the 1.34% arginine group had significantly higher the expression of the tight junction protein Zonula occludens-1 (ZO-1) at 6 days post-infection (dpi), whereas the 1.44% arginine group had the highest expression of ZO-1 and ZO-2 at 14 dpi, indicating that dietary arginine supplementation has positive effects on gut health in broilers under coccidiosis condition.

Summary

Coccidiosis is a common enteric disease caused by Eimeria species; it considerably reduces growth performance, nutrient digestibility, intestinal integrity, and gut health and increases mortality and economic loss for the poultry industry. Thus, nutrition strategies, such as supplementing pre- and probiotics, amino acids, and feed additives having anti-oxidant and anti-inflammatory properties, would improve growth performance and gut health in poultry. Moreover, precise determination of nutrient digestibility and requirements/functions of key amino acids under coccidiosis are essential to develop nutritional strategies to improve growth performance and alleviate negative effects of Eimeria infection in poultry.

References

Adams, C., H. A. Vahl, and A. Veldman. 1996. Interaction between nutrition and Eimeria acervulina infection in broiler chickens: development of an experimental infection model. Br. J. Nutr. 75:867-873.

Adedokun, S. A., and O. Adeola. 2016. The response in jejunal and ileal nutrient and energy digestibility and the expression of markers of intestinal inflammation in broiler chickens to coccidial vaccine challenge and phytase supplementation. Can. J. Anim. Sci. 97:258-267.

Allen, P. C. 1999. Effects of daily oral doses of L-arginine on coccidiosis infections in chickens. Poult. Sci. 78:1506-1509. doi: 10.1093/ps/78.11.1506.

Allen, P. C., and R. H. Fetterer. 2002. Recent advances in biology and immunobiology of Eimeria species and in diagnosis and control of infection with these coccidian parasites of poultry. Clin. Microbiol. Rev. 15:58-65. doi: 10.1128/cmr.15.1.58-65.2002

Amerah, A. M., and V. Ravindran. 2015. Effect of coccidia challenge and natural betaine supplementation on performance, nutrient utilization, and intestinal lesion scores of broiler chickens fed suboptimal level of dietary methionine. Poult. Sci. 94:673-680.

Atakisi, O., E. Atakisi, and A. Kart. 2009. Effects of Dietary Zinc and l-Arginine Supplementation on Total Antioxidants Capacity, Lipid Peroxidation, Nitric Oxide, Egg Weight, and Blood Biochemical Values in Japanase Quails. Biol. Trace Elem. Res. 132:136–143.

Ball, R. O., K. L. Urschel, and P. B. Pencharz. 2007. Nutritional consequences of interspecies differences in arginine and lysine metabolism. J. Nutr. 137:1626S–1641S.

Bortoluzzi, C., S. J. Rochell, and T. J. Applegate. 2018. Threonine, arginine, and glutamine: Influences on intestinal physiology, immunology, and microbiology in broilers. Poult. Sci. 97:937-945. doi: 10.3382/ps/pex394.

Blake, D. P., J. Knox, B. Dehaeck, B. Huntington, T. Rathinam, V. Ravipati, S. Ayoade, W. Gilbert, A. O. Adebambo, I. D. Jatau, M. Raman, D. Parker, J. Rushton, and F. M. Tomley. 2020. Re-calculating the cost of coccidiosis in chickens. Vet. Res. 51:115. doi: 10.1186/s13567-020-00837-2.

Bunchasak, C. 2009. Role of dietary methionine in poultry production. Poult. Sci. 46:169–179.

Castro, F.L.S., S. Su, H. Choi, E. Koo and W.K. Kim (2019) L-arginine supplementation enhances growth performance, lean muscle and bone density but not fat in broiler chicken.

Poultry Science 98:1716-1722. Castro, F.L.S, Y.H. Tompkins, R. Pazdro, and W.K. Kim. 2020a. The effects of total sulfur amino acids on the intestinal health status of broilers challenged with Eimeria spp. Poult. Sci. 99:5027–5036.

Castro, F. L. S., P. Y. Teng, S. Yadav, R. L. Gould, S. Craig, R. Pazdro, and W. K. Kim. 2020b. The effects of L-Arginine supplementation on growth performance and intestinal health of broiler chickens challenged with Eimeria spp. Poult. Sci. 99:5844-5857. Cervantes, H. M., L. R. McDougald, and M. C. Jenkins. 2020. Coccidiosis, Pages 1193-1217 in Diseases of Poultry, 14th Ed. Willey Blackwell. Hoboken, NJ, USA.123.

Chen, Y.P., X. Chen, H. Zhang, and Y.M. Zhou. 2013. Effects of dietary concentrations of methionine on growth performance and oxidative status of broiler chickens with different hatching weight. Br. Poult. Sci. 54:531–537.

Chen, Y. P., Y. F. Cheng, X. H. Li, W. L. Yang, C. Wen, S. Zhuang, and Y. M. Zhou. 2017. Effects of threonine supplementation on the growth performance, immunity, oxidative status, intestinal integrity, and barrier function of broilers at the early age. Poult. Sci. 96:405-413.

Corzo, A., E. T. Moran, Jr, and D. Hoehler. 2003. Arginine need of heavy broiler males: applying the ideal protein concept. Poult. Sci. 82:402–407.

Corzo, A., M. K. Kidd, W. A. Dozier, III, G. T. Pharr, and E. A. Koutsos. 2007. Dietary threonine need for growth and immunity of broilers raised under different litter conditions. J. Appl. Poult. Res. 16:574–582.

Duan, X., F. Li, S. Mou, J. Feng, P. Liu, and L. Xu. 2015. Effects of dietary L-arginine on laying performance and anti-oxidant capacity of broiler breeder hens, eggs, and offspring during the late laying period. Poult. Sci. 94:2938–2943.

Faure, M., C. Mettraux, D. Moennoz, J. P. Godin, J. Vuichoud, F. Rochat, D. Breuille, C. Obled, and I. C. Theulaz. 2006. Specific amino acids increase mucin synthesis and microbiota in dextran sulfate sodium-treated rats. J. Nutr. 136:1558–1564.

Fouad, A. M., H. K. El-Senousey, X. J. Yang, and J. H. Yao. 2013. Dietary L-arginine supplementation reduces abdominal fat content by modulating lipid metabolism in broiler chickens. Animal 7:1239–1245.

Gottardo, E. T., K. Prokoski, D. Horn, A. D. Viott, T. C. Santos, and J. I. Fernandes. 2016. Regeneration of the intestinal mucosa in Eimeria and E. Coli challenged broilers supplemented with amino acids. Poult. Sci. 95:1056-1065.

Jankowski, J., M. Kubińska, J. Juśkiewicz, A. Czech, K. Ognik, and Z. Zduńczyk. 2017. Effect of different dietary methionine levels on the growth performance and tissue redox parameters of turkeys. Poult. Sci. 96:1235–1243.

Khajali, F., and R. F. Wideman. 2010. Dietary arginine: metabolic, environmental, immunological and physiological interrelationships. Worlds Poult. Sci. J. 66:751–766.

Kidd, M. T., L. M. Pote, and R. W. Keirs. 2003. Lack of interaction between dietary threonine and Eimeria acervulina in Chicks. J. Appl. Poult. Res. 12:124-129.

Laika, M., and R. Jahanian. 2017. Increase in dietary arginine level could ameliorate detrimental impacts of coccidial infection in broiler chickens. Livest. Sci. 195:38-44. doi: 10.1016/j.livsci.2016.11.002

Liu, J.-L., and D. LeRoith. 1999. Insulin-like growth factor I is essential for postnatal growth in response to growth hormone. Endocrinology 140:5178–5184.

Luquetti, B. C., M. F. F. Alarcon, R. Lunedo, D. M. B. Campos, R. L. Furlan, and M. Macari. 2016. Effects of glutamine on performance and intestinal mucosa morphometry of broiler chickens vaccinated against coccidiosis. Sci. Agric. 73:322-327. doi: 10.1590/0103-9016-2015-0114.

Oxford, J. H., and R. K. Selvaraj. 2019. Effects of glutamine supplementation on broiler performance and intestinal immune parameters during an experimental coccidiosis infection. J. Appl. Poul. Res. 28:1279-1287. doi: 10.3382/japr/pfz095.

Parker, J., E. O. Oviedo-Rondon, B. A. Clack, S. Clemente-Hernandez, J. Osborne, J. C. Remus, H. Kettunen, H. Makivuokko, and E. M. Pierson. 2007. Enzymes as feed additive to aid in responses against Eimeria species in coccidia-vaccinated broilers fed corn-soybean meal diets with different protein levels. Poult. Sci. 86:643-653.

Paris NE, Wong EA. 2013. Expression of digestive enzymes and nutrient transporters in the intestine of Eimeria maxima-infected chickens. Poult. Sci. 92:1331–1335

Persia, M. E., E. L. Young, P. L. Utterback, and C. M. Parsons. 2006. Effects of dietary ingredients and Eimeria acervulina infection on chick performance, apparent metabolizable energy, and amino acid digestibility. Poult. Sci. 85:48-55.

Rao, R., and G. Samak. 2012. Role of Glutamine in protection of intestinal epithelial tight junctions. J. Epithel. Biol. Pharmacol. 5:47-54. doi: 10.2174/1875044301205010047.

Rochell, S. J., A. Helmbrecht, C. M. Parsons, and R. N. Dilger. 2016. Influence of dietary amino acid reductions and Eimeria acervulina infection on growth performance and intestinal cytokine responses of broilers fed low crude protein diets. Poult. Sci. 95:2602-2614.

Sakkas, P., I. Oikeh, D. P. Blake, M. J. Nolan, R. A. Bailey, A. Oxley, I. Rychlik, G. Lietz, and I. Kyriazakis. 2018. Does selection for growth rate in broilers affect their resistance and tolerance to Eimeria maxima? Vet. Parasitol. 258:88-98.

Santo, T., P. Teng, S. Yadav, F. Castro, R. Gould, S. Craig, C. Chen, A.L. Fuller, R. Pazdro, J. Sartori, and W.K. Kim. 2020. Effects of inorganic Zn and Cu supplementation on gut health in broiler chickens challenged with Eimeria spp. Front. Vet. Sci. 7:230.

Silva, L., A. E. Murakami, J. I. M. Fernandes, D. Dalla Rosa, and J. F. Urgnani. 2012. Effects of dietary arginine supplementation on broiler breeder egg production and hatchability. Rev. Bras. Cienc. Avic. 14:267–273.

Stipanuk, M.H. (2004) Sulfur amino acid metabolism: Pathways for production and removal of homocysteine and cysteine. Annu. Rev. Nutr. 24:539–577.

Su, S., K. B. Miska, R. H. Fetterer, M. C. Jenkins, and E. A. Wong. 2014. Expression of digestive enzymes and nutrient transporters in Eimeria acervulina-challenged layers and broilers. Poult. Sci. 93:1217-1226.

Su, S., K. B. Miska, R. H. Fetterer, M. C. Jenkins, and E. A. Wong. 2015. Expression of digestive enzymes and nutrient transporters in Eimeria-challenged broilers. Exp. Parasitol. 150:13-21.

Teng, P.-Y., J. Choi, Y. H. Tompkins, H. S. Lillehoj, and W. K. Kim. 2021. Impacts of increasing challenge with Eimeria maxima on the growth performance and the gene expression of biomarkers associated with intestinal integrity and nutrient transporters. Vet. Res. 52:81.

Teng, P.-Y., S. Yadav, T. Souza, A.L. Fuller and W.K. Kim. 2020a. 2-nitro-1-propanol improved nutrient digestibility, oocysts shedding, but not growth performance of Eimeria-challenged broilers. Poultry Science 99:4314-4322.

Teng, P. Y., S. Yadav, F. L. S. Castro, Y. H. Tompkins, A. L. Fuller, and W. K. Kim. 2020b. Graded Eimeria challenge linearly regulated growth performance, dynamic change of gastrointestinal permeability, apparent ileal digestibility, intestinal morphology, and tight junctions of broiler chickens. Poult. Sci. 99:4203-4216. doi: 10.1016/j.psj.2020.04.031.

Waldroup, P. W., F. J. Mussini, S. D. Goodgame, C. Lu, C. D. Bradley, and S. M. Fiscus. 2012. A nutritional approach to the use of anticoccidial vaccines in broilers: glutamine utilization in critical stages of immunity acquisition. Int. J. Poult. Sci. 11:243-246.

Yadav, S., P. Teng, T. Santos, R. Gould, S. Craig, A.L. Fuller, R. Pazdro, and W.K. Kim (2020). The effects of different doses of curcumin compound on growth performance, antioxidant status, and gut health of broiler chickens challenged with Eimeria species. Poult. Sci. 99:5936-5945.

Yi, G. F., G. L. Allee, C. D. Knight, and J. J. Dibner. 2005. Impact of glutamine and Oasis hatchling supplement on growth performance, small intestinal morphology, and immune response of broilers vaccinated and challenged with Eimeria maxima. Poult. Sci. 84:283–293.

Zhang, Q., X. Chen, S. D. Eicher, K. M. Ajuwon, and T. J. Applegate. 2017. Effect of threonine deficiency on intestinal integrity and immune response to feed withdrawal combined with coccidial vaccine challenge in broiler chicks. Br. J. Nutr. 116:2030-2043.