Dietary L-arginine supplementation enhances growth performance in yellow-feathered chickens

Yuanfan Deng
CJ BIO, China

Abstract

This study investigated the effects of dietary arginine (Arg) on performance in Chinese yellow-feathered chickens. One thousand and two hundreds one-day-old female *Qingyuan* partridge chickens were randomly assigned to 5 groups with 6 replicates of 40 birds each. Chickens were fed diets with 5 levels of total Arg (8.5, 9.7, 10.9, 12.1 and 13.3 g/kg) without antibiotics for 30 days. The average daily feed intake(ADFI), average daily gain(ADG), and feed conversion ratio(FCR) were improved with dietary Arg levels ($P < 0.05$). A diet containing 12.1 g Arg/kg of feed improved ADFI and ADG.

Introduction

In poultry, arginine (Arg) is an essential amino acid and is also a functional amino acid due to the lack of carbamoyl-phosphate synthetase and ornithine carbamoyl transferase in the urea cycle (Wu et al., 2009). Arg is an important substrate for protein synthesis and a precursor of many molecules such as nitric oxide, creatine, ornithine, glutamate, glutamine, polyamines, proline, and agmatine (Wu and Morris, 1998). Arginine and/or its derivatives enhance growth performance, reproduction, digestive enzymes secretion, nutrient transporters expression, antioxidative status, intestinal barrier function, and immunity (Duan et al., 2015; Hu et al., 2016; Gao et al., 2017; Xu et al., 2018; Castro et al., 2019; Zhang et al., 2020). The Arg requirements of modern strains of broiler chickens depends on age, sex and other variables (Cuca and Jensen, 1990; Labadan et al., 2001; Kidd et al., 2001; Chamruspollert et al., 2002). Arg requirements also vary greatly among species. To date, very little is known about the Arg requirements of Chinese yellow-feathered broiler chickens.

The *Qingyuan* partridge chicken is an important indigenous slow-growing breed in China that is very popular for its superior meat quality. The current study aimed to determine the effect of dietary Arg level on growth performance in *Qingyuan* partridge chickens reared without in-feed antibiotics and to determine the optimal dietary Arg requirement in a dose-dependent experiment.

Materials and Methods

Experimental Design, Diets, and Bird Husbandry

All experimental procedures were approved by the Animal Care and Use Committee of the Institute of Animal Science, Guangdong Academy of Agriculture Sciences and performed in accordance with animal welfare and ethics (GAASISA-2019-019). The trial used a completely randomized block design with 5 graded levels of total Arg. The control diet used corn gluten meal to achieve a low level of Arg (calculated 8.5 g/kg) but otherwise satisfied the nutritional requirements for *Qingyuan* partridge chickens for other nutrients (Table 1). The 4 additional treatments were the basal diet supplemented with 1.2, 2.4, 3.6 and 4.8 g/kg L-Arg (98.5% purity, CJ CheilJedang Co., Ltd, Shanghai, China) to make the dietary Arg level of 9.7, 10.9, 12.1, and 13.3 g/kg of diet. The Arg concentrations in diets were analyzed using a Hitachi L-8900 Amino Acid Analyzer (Hitachi High Technologies Corporation, Tokyo, Japan). The analyzed levels of dietary Arg were 8.7, 9.9, 11.0, 11.9, and 13.4 g/kg of diet, respectively.

A total of 1,200 one-day-old female *Qingyuan* partridge chicks (Guangdong Aijiankang Biotechnology Co., Ltd, Qingyuan, China) were randomly assigned to the 5 dietary treatments, each with 6 replicates of 40 birds. Each replicate was housed in 1 of 30 identical galvanized steel floor pens (length 160 cm × width 140 cm × height 40 cm; Guangzhou Muxing Poultry Equipment Co., Ltd, Guangzhou, China) with 8 water nipples and 2 feeders. All chicks were handled in accordance with the *Qingyuan* partridge chicken management guidelines for lighting, ad libitum feeding and allowed access to non-antibiotic tap water from 1 to 30 days. The temperature of the room was maintained at 32 to 35 ℃ for the first week and then reduced by 2 to 3 ℃ per week to a final temperature of 26 ℃.

Table 1. Feed formulation and nutrient content of the basal diet (as-fed basis)

Feed Components	g/kg	Nutrient composition[2]	g/kg
Corn	606.0	Metabolizable energy, MJ/kg	11.93
Wheat bran	135.0	CP	192.6
Soybean meal	90.0	Ca	9.5
Corn gluten meal	120.0	Total P	6.7
L-Lysine-HCI (98.5%)	4.7	Available P	4.4
DL-Methionine (99%)	0.9	Total Lys	9.9
L-threonine hydrochloride (98.5%)	1.3	Total Met	4.1
L-Tryptophan (98%)	0.2	Total Met+Cys	8.0
Limestone	13.2	Total Thr	7.2
Dicalcium phosphate	16.8	Total Trp	1.6
Sodium chloride	3.0	Total Ile	7.0
Premix[1]	10.0	Total Arg	8.7
Total	1000.0		

[1]The premix provided per kilogram of diet: vitamin A, 3,000 IU; vitamin D_3, 600 IU; vitamin E, 20 mg; vitamin K_3, 0.5 mg; vitamin B_1, 3.8 mg; vitamin B_2, 4.0 mg; vitamin B_6, 3.5 mg; vitamin B_{12}, 0.01 mg; choline, 1,300 mg; nicotinic acid, 25 mg; pantothenic acid, 10 mg; folic acid, 0.55 mg; biotin, 0.15 mg; Fe, 80 mg; Cu, 7.0 mg; Mn, 60 mg; Zn, 70 mg; I, 0.35 mg; Se, 0.23 mg
[2]Total Arg, Lys, Met, Met+Cys, Thr, Ile, and CP were measured values in the mixed feed. Each value is based on triplicate determinations. Other nutrient compositions are calculated values.

Growth Performance Determination

The birds were weighed per pen at day 1 and day 30 of the experiment. Feed consumption was recorded daily to determine the average ADFI. ADG and FCR were calculated. Mortality was recorded daily and was used to adjust the total number of birds per replicate to exclude them from calculations of ADFI and FCR.

Results

As shown in Table 2, ADFI increased in a linear manner ($P < 0.001$) with increasing dietary Arg. Means for BW at days 30, ADG and FCR demonstrated a linear and quadratic response ($P < 0.05$) to dietary Arg concentration.

Table 2. Effects of dietary L-arginine level on the growth performance of yellow-feathered chickens in the starter phase[1]

Indices[2]	Dietary Arg level, g/kg					SEM[3]	P-value		
	8.5	9.7	10.9	12.1	13.3		ANOVA	Linear	Quadratic
d1 BW (g)	31.30	31.34	31.44	31.38	31.41	0.067	NS	NS	NS
d30 BW (g)	262.2^{c}	281.6^{b}	$289.8^{a,b}$	$290.4^{a,b}$	296.9^{a}	3.018	<0.001	<0.001	<0.008
ADFI (g)	17.89^{b}	$18.23^{a,b}$	$18.70^{a,b}$	$18.97^{a,b}$	19.40^{a}	0.326	0.017	0.002	NS
ADG (g)	7.97^{c}	8.63^{b}	$8.91^{a,b}$	$8.93^{a,b}$	9.16^{a}	0.104	<0.001	<0.001	<0.009
FCR (g feed/g gain)	2.25^{a}	2.12^{b}	2.10^{b}	2.12^{b}	2.12^{b}	0.029	0.047	0.014	0.014
Mortality (%)	1.67	1.25	0.00	0.82	0.42	0.203	NS	NS	NS

[1]Means are based on 40 birds per pen and 6 replicate pens per diet.
[2]BW = body weight; ADFI = average daily feed intake; ADG = average daily gain; FCR = feed conversion ratio.
[3]Standard error of mean (n = 6).
NS = not significant.
a-cMeans with different superscripts within a main effect differ significantly ($P < 0.05$).

Discussion

Dietary Arg content had favorable effects on the ADFI, ADG, FCR, and 30-d BW in *Qingyuan* partridge chickens. Dietary Arg deficiency causes lack of appetite thus suppressing growth and development in broiler chickens and ducks (Kidd et al., 2001; Wang et al., 2014). Castro et al. (2019) also reported that dietary Arg supplementation increased ADFI, and improved ADG and feed efficiency in Ross 308 broiler chicks. Similarly, Xu et al. (2018) found improvements in ADG after increasing dietary Arg level in Arbor Acre broiler chicks. The results obtained here with a Chinese Yellow strain were consistent with the studies cited above. In contrast, others (Corzo et al., 2003; Ebrahimi et al., 2014) failed to demonstrate the various level of Arg supplementation had any effect on ADFI in broilers. Jahanian and Khalifeh-Gholi (2018) showed that high concentrations of Arg (13.75 g/kg) had no effect on ADG and FCR in Ross 308 broiler chicks aged 1 to 21 d, compared with recommended levels (NRC, 1994). In previous studies, Cuca and Jensen (1990) and NRC (1994) have suggested that Arg levels for Arbor Acre broiler chicks of 12.5 g/kg (1 to 21 d), and 11.0 g/kg (22 to 42 d) are appropriate. Castro et al. (2019) recommended that Arg levels for maximum BW gain of Ross 308 broiler chicks were 14.3 g/kg (1 to 10 d) and 13.4 g/kg (11 to 24 d). Ebrahimi et al. (2014) showed that the concentration of digestible Arg inducing the highest growth and muscle gain in Ross chicks were 22.0 g/kg (1 to 10 d) and 20.0 g/kg (11 to 24 d). Previous studies using various birds, strains and/or basal diets with different Arg concentrations have provided inconsistent requirements for dietary Arg level. The optimal dietary Arg concentration found here for maximum BW gain in *Qingyuan* partridge chickens (1 to 30 d) was 12.2 g/kg. In avian species, optimal concentration of Arg maximized protein biosynthesis and minimized protein degradation, which could explain the improvement in BW gain by dietary Arg supplementation (Yuan et al., 2016; Miao et al., 2017). Therefore, previous studies using different birds, strains and/or Arg concentrations in basal diet varied in responses to increasing dietary Arg level. As the prevalent meat chickens in southern China, optimizing nutrient provision for *Qingyuan* partridge chickens is of economic importance, so the present findings are relevant.

Conclusions

In conclusion, the present study with *Qingyuan* partridge chickens demonstrated that growth performance was improved by increasing dietary Arg. The optimal Arg levels for maximizing ADG and FCR were 12.2 and 11.0 g/kg, respectively.

REFERENCES

1. Castro, F. L. S., S. Su, H. Chio, E. Koo, and W. K. Kim. 2019. L-Arginine supplementation enhances growth performance, lean muscle, and bone density but not fat in broiler chickens. Poult. Sci. 98:1716-1722.
2. Chamruspollert, M., G. M. Pesti, and R. I. Bakalli. 2002. The influence of labile dietary methyl donors on arginine requirement of young broiler chicks. Poult. Sci. 81:1142-1148.
3. Corzo, A., E. T. Moran, and D. Hoehler. 2003. Arginine need of heavy broiler males: Applying ideal protein concept. Poult. Sci. 82:402-407.
4. Cuca, M., and L. S. Jensen. 1990. Arginine requirement of starting broiler chicks. Poult. Sci. 69:1377-1382.
5. Duan, X., F. Li, S. Mou, J. Feng, P. Liu, and L. Xu. 2015. Effects of dietary L-arginine on laying performance and antioxidant capacity of broiler breeder hens, eggs, and offspring during the late laying period. Poult. Sci. 94:2938-2943.
6. Ebrahimi, M., A. Z. Shahneh, M. Shivazad, Z. A. Pirsaraei, M. Tebianian, C. A. Ruizferia, M. Adibmoradi, K. Nourijelyani, and F. Mohamadnejad. 2014. The effect of feeding excess arginine on lipogenic gene expression and growth performance in broilers. Br. Poult. Sci. 55:81-88.
7. Gao, T., M. M. Zhao, L. Zhang, J. L. Li, L. L. Yu, P. A. Lv, F. Gao, and G. H. Zhou, 2017. Effects of in ovo feeding of l-arginine on the development of lymphoid organs and small intestinal immune barrier function in posthatch broilers. Anim. Feed. Sci. Tech. 225:8-19.
8. Gao, T., M. Zhao, L. Zhang, J. Li, L. Yu, P. Lv, F. Gao, and G. Zhou. 2017. Effect of in ovo feeding of L-arginine on the hatchability, growth performance, gastrointestinal hormones, and jejunal digestive and absorptive capacity of posthatch broilers. J. Anim. Sci. 95:3079-3092.
9. Hu, Y., J. Tan, J. Qi, and H. Zhang. 2016. Regulatory effects of dietary L-Arg supplementation on the innate immunity and antioxidant ability in broiler chickens. J. Inter. Agr. 15:2578-2587.
10. Huang, Y., X. Shi, Z. Li, Y. Shen, X. Shi, L. Wang, G. Li, Y. Yuan, J. Wang, Y. Zhang, L. Zhao, M. Zhang, Y. Kang, and Y. Liang. 2018. Possible association of Firmicutes in the gut microbiota of patients with major depressive disorder. Neuropsych Dis. Treat. 14:3329-3337.
11. Jahanian, R. 2009. Immunological responses as affected by dietary protein and arginine concentrations in starting broiler chicks. Poult. Sci. 88:1818-1824.
12. Jahanian, R., and M. Khalifeh-Gholi. 2018. Marginal deficiency of dietary arginine and methionine could suppress growth performance and immunological responses in broiler chickens. J. Anim. Physiol. Anim. Nutri. 102:11-20.
13. Kidd, M. T., E. D. Peebles, S. K. Whitmarsh, J. B. Yeatman, and R. F. Wideman. 2001. Gowth and immunity of broiler chicks as affected by dietary arginine. Poult. Sci. 80:1535-1542.
14. Labadan, M. C., K. N. Hsu, and R. E. Austic. 2001. Lysine and arginine reguirements of broiler chickens at two-to three-week intervals to eight weeks of age. Poult. Sci. 80:599-606.
15. Liang, M., Z. Wang, H. Li, L. Cai, J. Pan, H. He, Q. Wu, Y. Tang, J. Ma, and L. Yang. 2018. L-arginine induces antioxidant response to prevent oxidative stress via stimulation of glutathione synthesis and activation of Nrf2 pathway. Food. Chem. Toxicol. 115:315-328.
16. Miao, L. P., C. Yuan, X. Y. Dong, X. Y. Zhang, M. Y. Zhou, and X. T. Zou. 2017. Effects of dietary L-arginine levels on small intestine protein turnover and the expression of genes related to protein synthesis and proteolysis of layers. Poult. Sci. 96:1800-1808.
17. National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.
18. Tan, J. Z., Y. M. Guo, T. J. Applegate, E. C. Du, and X. Zhao. 2015. Dietary L-arginine modulates immunosuppression in broilers inoculated with an intermediate strain of infectious bursa disease virus. J. Sci. Food. Agri. 95:126-135.
19. Tan, J., S. Liu, Y. Guo, T. J. Applegate, and S. D. Eicher. 2014a. Dietary L-arginine supplementation attenuates lipopolysaccharide-induced inflammatory response in broiler chickens. Brit. J. Nutr. 111:1394-1404.
20. Tan, J., T. J. Applegate, S. Liu, Y. Guo, and S. D. Eicher. 2014b. Supplemental dietary L-arginine attenuates intestinal mucosal disruption during a coccidial vaccine challenge in broiler chickens. Brit. J. Nutr. 112:1098-1109.
21. Tang, D., J. Wu, H. Jiao, X. Wang, J. Zhao, and H. Lin. 2019. The development of antioxidant system in the intestinal tract of broiler chickens. Poult. Sci. 98:664-678.
22. Wang, B., Y. Liu, L. Feng, W. D. Jiang, S. Y. Kuang, J. Jiang, S. H. Li, L. Tang, and X. Q. Zhou. 2015. Effects of dietary arginine supplementation on growth performance, flesh quality, muscle antioxidant capacity and antioxidant-related signaling molecule expression in young grass carp (Ctenopharyngodon idella). Food chemistry. 167: 91-99.
23. Wang, C., S. S. Hou, W. Huang, T. S. Xu, G. H. Rong, and M. Xie. 2014. Arginine affects appetite via nitric oxide in ducks. Poult. Sci. 93:2048-2053.
24. Wang, W., Y. Lee, H. Lu, C. Chou, and C. Wang. 2019. Analysis of gut microbiota and effect of lauric acid against necrotic enteritis in Clostridium perfringens and Eimeria side-by-side challenge model. Plos One. 14:e0205784.
25. Wu, G., F. W. Bazer, T. A. Davis, S. W. Kim, P. Li, J. M. Rhoads, M. C. Satterfield, S. B. Smith, T. E. Spencer, and Y. Yin. 2009. Arginine metabolism and nutrition in growth, health and disease. Amino Acids. 37:153-168.
26. Wu, G., S. M. Morris. 1998. Arginine metabolism: nitric oxide and beyond. Biochem. J. 336:1-17.
27. Wu, M., H. Xiao, F. Shao, B. Tan, and S. Hu. 2020. Arginine accelerates intestinal health through cytokines and intestinal microbiota. Int. Immunopharmacol. 81:106029.
28. Xu, Y. Q., Y. W. Guo, B. L. Shi, S. M. Yan, and X. Y. Guo. 2018. Dietary arginine supplementation enhances the growth performance and immune status of broiler chickens. Livest. Sci. 209:8-13.
29. Yuan, C., X. C. Bu, H. X. Yan, J. J. Lu, and X. T. Zou. 2016. Dietary L-arginine levels affect the liver protein turnover and alter the expression of genes related to protein synthesis and proteolysis of laying hens. Poult. Sci. 95:61-267.
30. Zhang, B., G. Li, M. S. Suhaib, L. Gan, H. Fan, Z. Lv, and Y. Guo. 2020. Dietary L-arginine supplementation ameliorates inflammatory response and alters gut microbiota in broiler chickens infected with Salmonella enterica serovar Typhimurium. Poult. Sci. 99:1862-1874.
31. Zhang, B., Z. Lv, H. Li, S. Guo, D. Liu, and Y. Guo. 2017. Dietary L-arginine inhibits intestinal Clostridium perfringens colonization and attenuates intestinal muscoal injury in broiler chickens. Brit. J. Nutr. 118:321-332.
32. Zhang, B., Z. Lv, Z. Li, W. Wang, G. Li, and Y. Guo. 2018. Dietary L-arginine supplementation alleviates the intestinal injury and modulates the gut microbiota in broiler chickens challenged by Clostridium perfringens. Front. Microbiol. 9:1716.