The role of arginine in intestinal health, heat stress, and growth performance of broiler chickens

Dong Xiao li
CJ Bio, China

Introduction

L-arginine is a basic amino acid with the molecular formula of $C_6H_{14}N_4O_2$. It contains a guanidine group, one amino group, and one carboxylic acid. Arginine is the most abundant nitrogen carrier in tissue protein. For mammals, arginine is a conditionally essential amino acid. However, poultry cannot synthesize arginine itself and must be obtained from exogenous sources. So arginine is an essential amino acid for poultry.

Arginine is an essential amino acid for broiler

Uric acid is the vehicle for nitrogen excretion in poultry metabolism. It originates from the purines which derive their nitrogen from amino acids. Therefore, arginine would not be expected to function in nitrogen transfer to the extent that is does in animals with an ornithine cycle (Figure 1). Klose (1938) and Leveille (1959) studied that arginine is essential for the growing chick as well as the adult bird. Arginine could not be replaced by ornithine and citrulline. Tamir and Ratner (1963) found that carbamyl phosphate synthetase has not been detected in any tissue, while ornithine transcarbamylase, argininosuccinate synthetase, and argininosuccinase lyase have been found in the kidney but not in the liver. Small amounts of argininosuccinate lyase activity were also presented in the spleen, pancreas, and intestinal tract (Table 1). Jones et al. (1961) studied the enzymes of arginine metabolism in rats (Table 1). Compared to the enzymes in rats, it can be concluded that arginine is essential for broiler because they lack carbamyl phosphate synthetase.

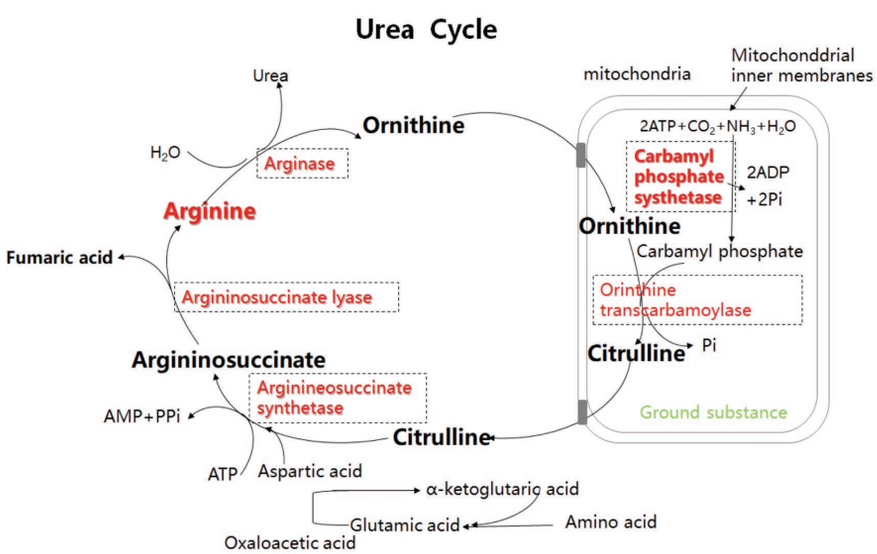


Figure 1. Urea cycle diagram of arginine synthesis

Table 1. Distribution of enzymes of arginine synthesis and arginase in chick and rat organs

Species	Organ	Carbamyl phosphate synthetase	Ornithine transcarbamylase	Arginino-succinate synthetase	Argininosuccinate lyase	Arginase
Rat	liver	340	14,500	182	310	35,900
	Kidney	8	5	22	16	3100
	Pancreas	3	2			
	Spleen	0	0			
Chick	Liver	0	0	0	0	240
	Kidney	0	9	10	11	6,880
	Pancreas				1	
	Spleen				4	
	Intestinal tract				1	

All values are expressed as micromoles product formed/hr./g. wet wt.

Nutritional effect of arginine in broilers

The requirements of arginine in broilers

Arginine is an essential amino acid for broilers. The arginine requirement in broilers is affected by many factors such as breed, environment, etc. A comparison of the feeding standards provided by broiler breeding companies is shown in Table 2. It can be found that the arginine requirement of Ross 308/708 is higher than COBB and Hubbard. Moreover, Corzo (2020) indicated that the ratio of dArg/dLys increased as the birds age increased. The optimum dArg/dLys value to optimize BW gain and FCR from 1-14d was 106 for both parameters, however, it was determined to be 129 and 116 from 25 - 42d, respectively.

The arginine requirement also increased in broilers fed diets without antibiotics. Ruan et al. (2020) demonstrated that growth performance of Qingyuan partridge chickens, which belong to the yellow-feather broiler, was improved by increasing dietary Arg from 8.5 to approximately 12.0 g/kg in antibiotic-free diets. The study also showed that ileal secretary IgA levels were increased by Arg supplementation. Secretory IgA is the primary immunologic barrier preventing intraluminal pathogens from colonizing the intestinal mucosa, and this aids in maintaining homeostasis with the commensal microbiota. It may be expected that arginine plays important roles in intestinal health and immunity.

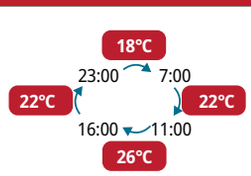
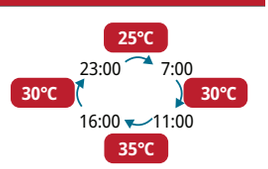
Table 2. The arginine requirement recommended by broiler breeder companies

Growth stage	Age /d	Breed	Lys (dig %)	Arg (dig %)	Arg/Lys
Starter	0-10	Cobb 500	1.18	1.24	1.05
	0-10	Cobb 700	1.22	1.28	1.05
	0-10	Hubbard (slaughter weight 1.8-2.0)	1.27	1.33	1.05
	0-10	Hubbard (slaughter weight 2.5-3.0)	1.23	1.29	1.05
	0-10(Target live weight≤1.6kg)	Ross 308/708	1.28	1.37	1.07
	0-10(Target live weight 1.7-2.4kg)	Ross 308/708	1.28	1.37	1.07
	0-10(Target live weight 2.5-3kg)	Ross 308/708	1.28	1.37	1.07
Grower	11-22	Cobb 500	1.05	1.1	1.05
	11-22	Cobb 700	1.08	1.13	1.05
	11-22	Hubbard (slaughter weight 1.8-2.0)	1.13	1.19	1.05
	11-22	Hubbard(slaughter weight 2.5-3.0)	1.09	1.15	1.06
	11-24(Target live weight≤1.6kg)	Ross 308/708	1.15	1.23	1.07
	11-24(Target live weight 1.7-2.4kg)	Ross 308/708	1.15	1.23	1.07
	11-24(Target live weight 2.5-3kg)	Ross 308/708	1.15	1.23	1.07
Finisher	23-42	Cobb 500	0.95	1.03	1.08
	23-42	Cobb 700	0.98	1.06	1.08
	23-30	Hubbard (slaughter weight 1.8-2.0)	1.07	1.15	1.07
	23-30	Hubbard (slaughter weight 2.5-3.0)	1.04	1.11	1.07
	25-market	Ross 308/708	1.06	1.13	1.07
	25-market	Ross 308/708	1.03	1.1	1.07
	25-39(Target live weight 2.5-3.0)	Ross 308/708	1.02	1.09	1.07

The arginine requirement increases in heat stress

From market application experience, the requirement of arginine in broiler was different in different seasons. In summer, nutritionists might appropriately increase the arginine level of the diets in order to avoid poor growth performance. Brake (1998) studied that increasing Arg:Lys ratio at high temperatures resulted in consistent improvements in feed conversion without any loss in growth (The results shown in Figure 2, and the experiment design is shown in Table 3). Under heat stress, the organs such as the small intestine, liver, and spleen are experiencing ischemic and hypoxic conditions. Arginine was shown to have an important role in vasodilation and adversely changing blood flow. That may be arginine plays functional roles under heat stress.

Table 3. Experiment design of arginine on heat stress in broiler

	Experiment 1		Experiment 2	
Treatment	Thermoneutral	Heat stress	Thermoneutral	Heat stress
Temperature	20℃	31℃		
Arg/Lys%	1.09/1.36		1.10/1.37	
Age of broiler	20-41d		20-47d	

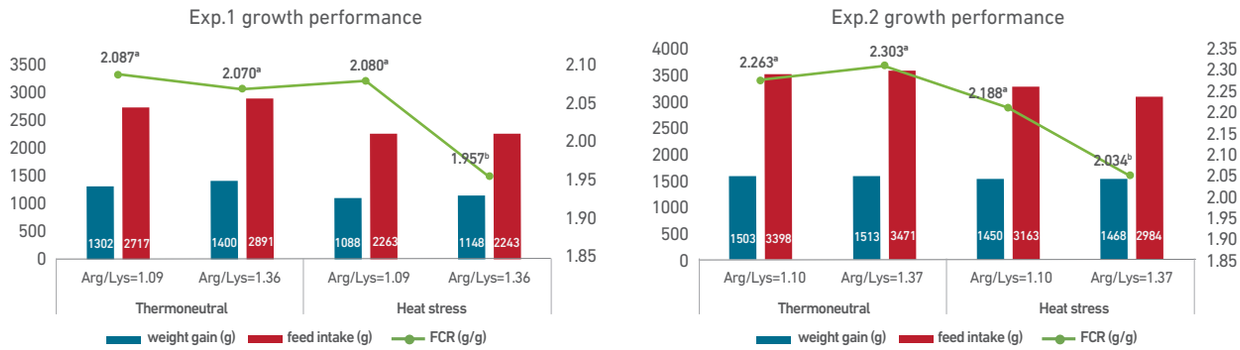


Figure 2. The effect of arginine on heat stress

Arginine content in feed ingredients

With the problem of food security, the diversification of raw materials in broiler diets is imperative. However, the arginine content of raw materials varies greatly (Figure 3). Some raw materials are rich in arginine, such as peanut and cottonseed meals. Other raw materials such as corn gluten meal and whey powder are poor in arginine. In summer, the supply of peanut and cottonseed meals is limited in China. Meanwhile, the arginine requirement of broiler increases. Therefore, the supplementation of crystalline arginine in broiler diets during summer is a useful tool to maintain performance.

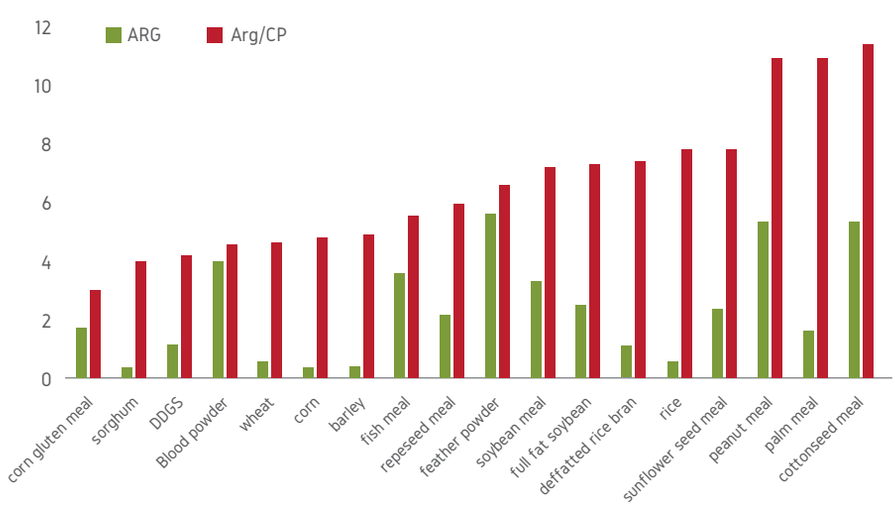


Figure 3. Comparison of arginine content in common feed material

Source : Chinese feed database(2020)

Functional effect of arginine in broiler

Improve intestinal health

Zhang(2018) conducted six experiments to study the effects of L-arginine supplementation on the intestinal mucosal injury induced by the intestinal pathogenic bacteria in broiler chickens and related mechanisms. One experiment demonstrated L-arginine supplementation could inhibit Clorstridium perfringens overgrowth and alleviate intestinal mucosal injury by promoting innate responses and maintaining intestinal barrier function. Dietary L-arginine supplementation prevented C. perfringens challenge-induced circulated arginine deficiency and normalized arginine transport and metabolism. L-arginine also plays role in down-regulated the activated JAK-STAT (jejunal Janus kinase, signal transducer and activator of transcription) signaling pathway. Another, L-arginine alleviated the intestinal inflammation and mucosal injury of chicken challenged by Clorstridium perfringens. The arginine supplemented diet fed during the whole period exhibited more beneficial effects than that only fed during the infection stage.

Improve immunity

Tan (2014) studied the effects of dietary L-arginine supplementation on growth performance, immunosuppression, inflammation, and intestinal barrier dysfunction in broiler chickens. The results demonstrated that additional dietary arginine supplementation is required to get the optimal growth performance and immune function for immunosuppressive broilers, and arginine supplementation attenuated IBDV (Infectious Bursal Disease Vaccine) inoculation induced immunosuppression via modulating circulating T cell subpopulations. Dietary arginine supplementation attenuated intestinal mucosal disruption of coccidiosis-challenged chickens probably through suppressing TLR4 and activating mTOR complex 1 pathway, and attenuated the overexpression of pro-inflammatory cytokines probably through the suppression of the TLR4 pathway and CD14+ cells percentage.

Conclusion

Arginine is an essential amino acid in poultry. It plays a nutritional and functional role in broilers. The requirement of arginine is increased in antibiotic-free diets and during heat stress in order to ensure the growth performance of broilers.

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