Metabolic & performance benefits of L-Arginine over guanidinoacetic acid

There are at least five commercially available synthetic amino acids, namely methionine, lysine, threonine, tryptophan and valine.

Currently, arginine (Arg) is available which is produced through bio-fermentation. L-Arg is an essential amino acid for chickens due to the unavailability of two separate enzymes in the urea cycle in the kidney and almost all urea cycle enzymes in the liver.

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The mammalian cells have a fully functional urea cycle. Therefore L-Arg is not an essential amino acid in swine. However, new data shows that endogenous arginine synthesis through the urea cycle is not enough to cover arginine requirements in swine. Thus, arginine is named to be essential, for example in piglets as well.

In fact, GAA is the precursor of creatine which is synthesised via a two step process involving two enzymes and three amino acids: arginine, glycine, and methionine.

In the first step, arginine: glycine amidino-transferase (AGAT) transfers an amidino group from arginine to the amino group of glycine to produce guanidinoacetate (GAA) and ornithine.

$$\text{Glycine} + \text{Arginine} \xrightarrow{\text{(AGAT)}} \text{Ornithine} + \text{GAA}$$

In the second step, GAA methyltransferase (GAMT) employs S-adenosylmethionine (SAM) to methylate GAA, producing creatine and S-adenosylhomocysteine (SAH).

$$\text{GAA} + \text{SAM} \xrightarrow{\text{(GAMT)}} \text{Creatine} + \text{SAH}$$

L-Arg and GAA are used in practice in order to cover arginine requirements of the animals. Thus, understanding the differences between the two products is important.

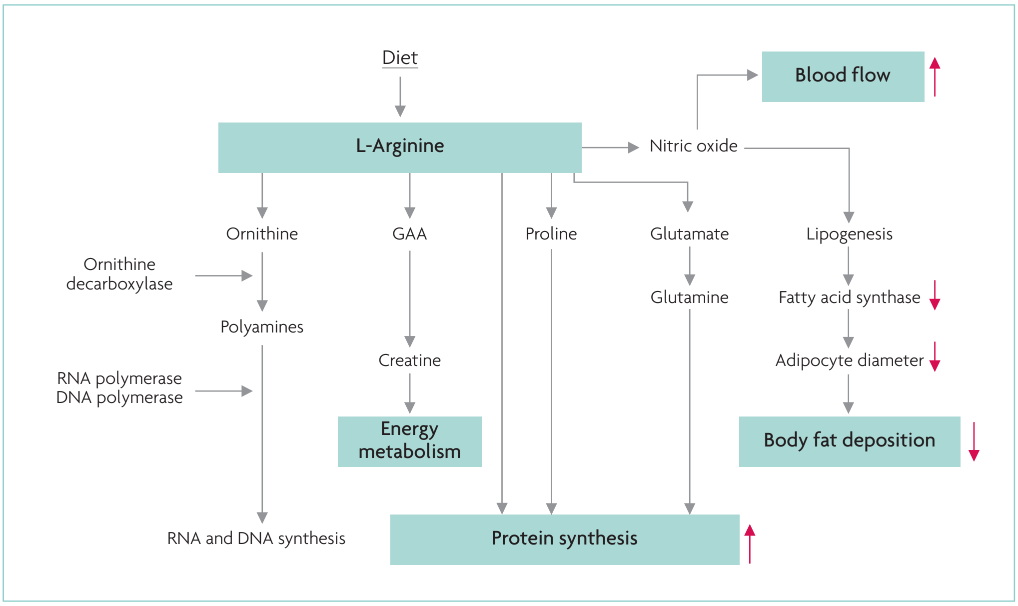


Fig. 1. Role of L-Arg in different metabolic pathways (Modified from Fouad et al., 2012).

Metabolism of L-Arg and GAA

L-Arg not only serves as building blocks of proteins, for example, in muscles but also performs several other vital metabolic functions. Moreover, L-Arg serves as a substrate for the biosynthesis of different molecules such as nitric oxide, GAA, glutamate, ornithine and proline.

Nitric oxide as an important mediator of vasodilation contributes to an increase of blood flow to the organs. Nitric oxide also reduces fat synthesis and promotes fat oxidation. L-Arg also improves the carcase yield especially the breast muscles in broilers via formation of glutamate and proline.

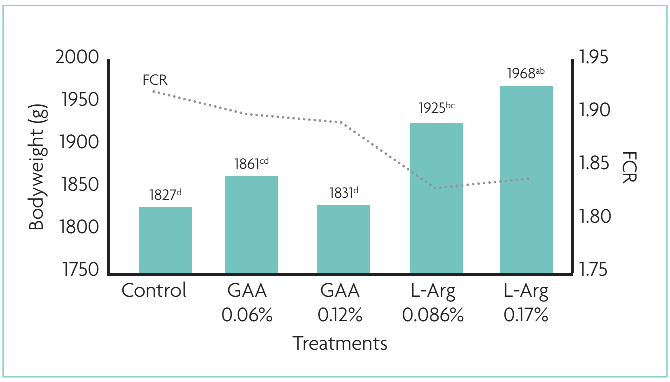
Glutamate, proline and hydroxy-proline are also required for the synthesis of connective tissues.

Similarly, other molecules synthesised from the L-Arg metabolism including ornithine and polyamines contribute in DNA and RNA synthesis for normal cellular growth.

GAA is an endogenous metabolite of Arg which participate in muscle energy buffering system (Fig. 1).

High cellular concentration of GAA has a negative feedback on AGAT, thus endogenous synthesis of GAA will not happen when enough GAA is added through the diet.

Fig. 2. Comparison of L-Arg and GAA in broilers under challenging conditions (cold stress).



Comparative performance studies:

- Study I:

Ascites, cardiovascular metabolic disorder, is a major challenge under cold stress conditions. It was hypothesised that providing extra Arg can reduce ascites incidences in broilers.

Emami et al. (2016) investigated the effect of L-Arg (0.86-1.72g/kg of feed) and GAA (0.6-1.2g/kg of feed) under cold stress condition. The digestible Arg to digestible Lys ratio was 107:100 in the basal diet.

The temperature of one house was according to optimal conditions, whereas the temperature in the

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second house was gradually decreased to 17°C from day 14 onward to the end of the experiment in order to induce ascites.

The L-Arg group significantly ($p<0.05$) increased body weight (BW) and reduced FCR as compared to the basal diet and the GAA group (Fig. 2). The authors concluded that arginine can help in broiler production under challenging conditions.

Study II:
Dilger et al., (2013) showed significantly higher BWG in the L-Arg supplemented group as compared to diets supplemented with only GAA or creatine ($p<0.05$).

Adding GAA and creatine on top of L-Arg does not cause any further improvement (Fig. 3).

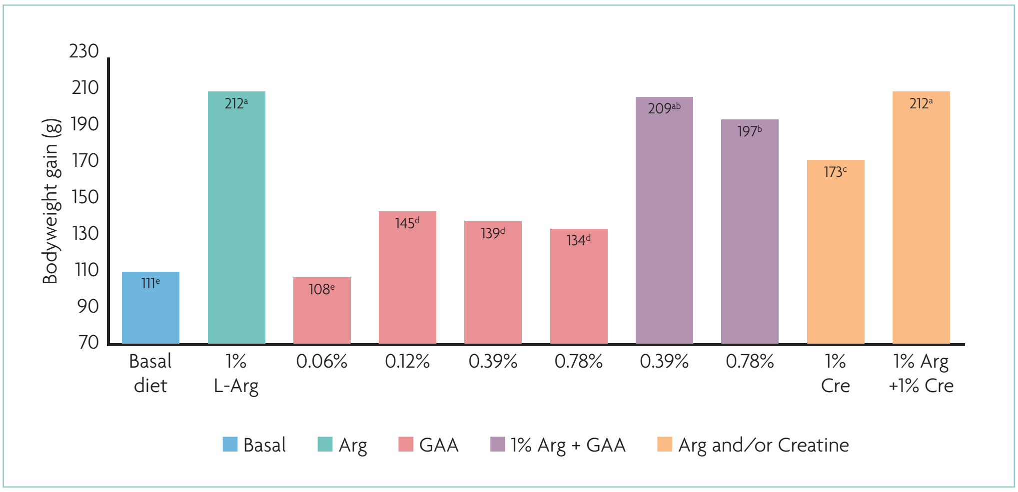

Fig. 3. Comparison of L-Arg, GAA and creatine supplemented diets in broilers (8-17 days).

Estimations on the arginine sparing effect of GAA

The L-Arg sparing effect of GAA is not fully revealed. However, findings from literature could indicate the estimated contribution of protein bound L-Arg into GAA synthesis.

In the presence of dietary GAA supplementation, we assume that no L-Arg is being used for internal GAA synthesis, which can give us an idea about the Arg sparing effect of GAA.

Since the L-Arg is the essential amino acid in poultry and conditionally essential in swine, there are specific dietary requirements for the L-Arg contributed by the raw materials.

De novo Synthesis of GAA is contributed by Gly, Met and Arg. Gly molecule is used as such, however, in case of Met only methyl group and in case of Arg only amidino group are incorporated.

In both situations Met and Arg can be resynthesised in their respective cycles.

Brosnan et al., (2009) calculated the contribution of the three amino acids in the creatine synthesis in growing piglets. Around 35% of dietary Met and 20% of dietary Arg contribute to the synthesis of creatine.

However, Wu et al., (2004) have estimated that around 17% of milk Arg may be used for creatine synthesis in piglets. Thus, by using GAA, the animal needs 35% extra methionine and can save 20% of dietary Arg. Moreover, Luiking et. al., (2012) concluded that creatine synthesis consumes around 20-30% of the Arg's amidino groups, whether provided in the diet or synthesised within the body. These findings indicate that if sufficient GAA is supplemented in the animal diet, it may spare up to 20-30% of the protein deposited Arg. ■

References are available from the author on request