Balancing low crude protein diets : histidine as a next limiting amino acid in swine

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Introduction

Growing concerns about the environmental impacts of animal production is an important driver for low crude protein (CP) strategies in modern fattening practices. Reducing the nitrogen (N) intake has a significant effect on N excretion and on subsequent environmental N load. On average, each 1% decrease in CP lead to a reduction of nearly 2.8 % N excretion (Wang et al., 2018). Additionally, high protein intake can lead to protein fermentation in the hindgut. This is a particularly true in weaning piglets associated with gastrointestinal disorders like post-weaning diarrhea (Nyachoti et al., 2006, Wellock et al., 2008). In cereal based diets, histidine may become next limiting after valine and isoleucine. Due to the relative low content of histidine in barley, especially barley rich rations may need supplementation with L-histidine. When new supplementary amino acids like isoleucine and histidine are entering the market and are economically feasible, the possibility occurs for a further CP reduction in swine diets. However, when dietary CP level decreases too much, a loss in performance of the animals may occur due to the lack of proper balance of essential and non-essential amino acids. Therefore, knowledge about use of new feed grade amino acids in commercial diets is needed to reduce feed costs, to support animal health, and to maintain optimal animal performance.

Physiological roles of histidine

Besides hair, histidine is present in relative high amounts in the whole body of piglet (Kyriazakis et al., 1993). Histidine plays a vital role in the formation of hemoglobin, the oxygen-transport system in the red blood cells. Easter and Baker (1977) performed experiments with histidine supplementation in gilts during the last third of pregnancy. Even though the blood chemistry of gilts itself were not affected, their offspring had notable lower blood hemoglobin concentrations when gilts were fed a histidine-free diet.
The amino acids beta-alanine and histidine together form a dipeptide called carnosine; which is especially highly concentrated in muscle and brain tissue (Kohen et al., 1988, O'Dowd et al., 1988). Carnosine has various biological functions such as pH buffering and anti-oxidation (Bao et al., 2015). Carnosine supplementation enhances the meat quality by decreasing drip losses, increasing redness color value and reducing malondialdehyde and carbonyl protein complexes concentrations in muscle tissue (Ma et al., 2010). Supplemental dietary L-histidine may increase the amount of carnosine in the muscle tissue and consequently increases the antioxidative status in the swine meat. This hypothesis was confirmed in a feeding trial with broilers (Park et al., 2013), but the same working group failed to show comparable results in pig meat (Park et al., 2014). However, Park et al. (2014) didn´t use supplementary L-histidine that was used in the broiler trial, but used blood-meal as a source of histidine in the swine trial. Blood cells have high amounts of histidine and also leucine and phenylalanine. Thus, these amino acids may have inhibited each other as they compete for the same transporter (Pardridge, 1977). Further investigations are needed to clarify the connection between histidine supplementation and carnosine content in pig meat.

Histidine is also a precursor of the neurotransmitter histamine. Histamine plays an important role in the regulation of feed intake through its modulating effects in the brain satiety centers (Kurose and Terashima, 1999). Although excess dietary intake of histidine causes anorexia in rats (Kasaoka et al., 2004), in dose-response trials with piglets this effect was not detectable up to a ratio of 44:100 (Cemin et al., 2018). On the other hand, growth trials consistently find a markedly reduce feed intake in piglets fed histidine deficient diets (Gloaguen et al., 2013, Wessels et al., 2016, Cemin et al., 2018).

Histamine is also involved in the inflammatory response. Histamine is released from mast cells during immune reaction. The relation of histidine and histamine has been investigated in knock-out mice missing the enzyme histidine decarboxylase gene. The mice are not able to synthesize histamine from histidine therefore, exhibit a reduced number of mast cells. Moreover, the mast cells show morphology changes with reduced granular content (Ohtsu et al., 2001).

Histidine requirements in swine

Considering established nutritional recommendation standards like the NRC (2012) or the BSAS (2003), the optimal SID His to Lys ratio is 34 %. Chung and Baker (1992) initially suggested an optimal His:Lys ratio of 32 % in 10 kg piglets. Heger et al. (2003) estimated a slightly higher ratio of His to Lys (33%) when using nitrogen retention as the response criteria.
More recent data derived from dose-response trials suggest that these values may overestimate the histidine requirements of pigs (Table 1). On average the published research suggest a SID His:Lys ratio of 29.8 % (± 2.50) for ADG as response and slightly lower requirements of 29.0 % (± 2.07) for G:F. The latest revision of the Danish nutrient standards (Tybirk et al., 2020) state the requirements for Histidine has been reduced to 29 – 31 % of dietary lysine content.

Table 1. Estimated SID His:Lys ratios for weaning piglets derived from dose-response trial by different authors

Authors	Response criterium	Estimated histidine requirement [%]	Statistical model
Gloaguen et al., 2013	ADG	31.6	Curvilinear-plateau
	G:F	28.8	
Wessels et al., 2016	ADG	26.5	Broken-line linear
		27.9	Curvilinear-plateau
		33.3	Quadratic-function
	G:F	26.5	Broken-line linear
		27.8	Curvilinear-plateau
		32.6	Quadratic-function
Cemin et al., 2018, Experiment 1	ADG	29.7	Broken-line linear
	G:F	29.8	
Cemin et al., 2018, Experiment 2	ADG	31.0	Broken-line linear
	G:F	28.6	
Average	ADG	29.8 ± 2.50	-
	G:F	29.0 ± 2.07	

Conclusion

With new feed grade amino acids isoleucine and especially histidine entering the market, lower CP strategies are possible. Based on the latest literature, the histidine requirement to optimize growth performance is between 29 – 31 % of dietary lysine. L-histidine feed grade offer the opportunity for precision formulation, which can reduce feed production cost and can increase the environmental sustainability of pork production.

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