OPINION LEADER

A swine nutritionist perspective on managing amino acid nutrition in reduced crude protein diets

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Abstract

The desire of swine nutritionists to lower crude protein (CP) as a means to reduce diet costs and improve nutrient utilization continues to be of great importance. The increased availability and cost competitiveness of synthetic amino acids (AA) has allowed swine nutritionists to formulate diets with reduced crude protein (CP) compared to more typical formulations of the past. Today, one of the primary benefits of this low CP approach is to lessen the amount of nitrogen substrates available for proliferation of pathogenic bacteria in order to minimize post-weaning diarrhea (PWD). Swine diets are normally formulated on an ileal digestible amino acid basis (SID) and frequently contain feed grade lysine (Lys), threonine (Thr), methionine (Met), tryptophan (Trp), valine (Val), and isoleucine (Ile). Recent confirmations of the histidine requirement for growing pigs may lead to feed grade histidine entering formulations when it becomes economically available. Maintaining proper AA levels

and ratios to meet the system goals is important and utilizing the SID Lys:CP ratio at or below 6.35 helps nutritionists ensure there is enough nitrogen for endogenous non-essential AA production. In post-weaning diets, reducing CP to approximately 19.5% (from a typical 21 - 22%) by using feed grade AA-supplemented diets allows for reduced PWD without negatively impacting growth performance while additional reductions in CP will further reduce PWD, but some loss in performance will be observed. Opportunities to reduce SID Lys and CP in early post-wean diets and taking advantage of compensatory gain in later phases is a routine strategy to control PWD while maintaining nursery ending weights. In finishing pigs, recent AA modeling to predict growth performance has defined important relationships between branch-chain AA as well as large-neutral AA (Trp) such that when high levels of Leu are present in diets, increased Val, Ile, and Trp are needed to maintain growth performance. Subsequent research has confirmed the accuracy of the models and illustrated that increased Val, Ile, and/or Trp added at levels above normally accepted levels to support growth can ameliorate some of the poorer performance observed when diets contain high levels of Leu. It is expected that swine nutritionists will continue to focus on utilizing increased levels of feed grade AA and reducing CP as a means to control diet cost and optimize growth performance and health status of pigs.

Introduction

Reducing crude protein (CP) in swine diets without negatively impacting performance continues to be a focus area for swine nutritionists just as it has been for over the last 30 years. The initial drive for lower CP in swine diets was to reduce the amount of unused nitrogen excreted into the environment and this is still a key component of the increased attention placed on improving sustainability of the global swine industry. However, another motivator to reduce CP is to reduce diet cost and improve swine production profitability. The increased availability and lower cost of feed-grade amino acids allows nutritionists to formulate diets with lower CP and reduce diet cost because increased levels of these feed-grade amino acids can be included in the diets to replace the more expensive plant or animal based protein and amino acid sources.

Today, it is not unusual for swine nutritionists to include 6 feed-grade amino acids in diets when they are needed to meet the pig's requirements and they would include lysine, methionine, threonine, tryptophan, valine, and isoleucine.

Recently, Cemin (2018) helped determine the histidine requirements of pigs (< 31% SID His:Lys depending on the response criteria of interest) and an increasing supply of feed-grade histidine could mean that in the near future the 7th feed-grade amino acid could be routinely utilized. The amount of feed grade lysine utilized in swine diets has also increased with the increased availability of other feed-grade amino acids. Diets formulated at the turn of this century routinely contained a maximum of 0.15% of feed-grade lysine whereas now it is not uncommon to have up to 0.60% of feed grade lysine included in

diets. All of these factors create an enhanced need for proper diet formulation in relation to amino acid levels and relationships to each other.

Amino acid formulation principles in swine diets

In order to take advantage of the benefits associated with utilizing higher amounts of feed-grade amino acids, swine nutritionists must formulate diets based on achieving optimum levels of digestible amino acids, not total amino acids. Typically, standardized ileal digestible (SID) coefficients (NRC, 2012) are used in diet formulation to convert the total amino acids analyzed in ingredients to a digestible basis. After the nutritionist establishes the dietary energy constraints around the system production goals, they will next establish the lysine content of the diet, formulating based on a SID lysine:calorie ratio. Research conducted by genetic companies, universities, and commercial producers provides the basic knowledge for choosing the correct lysine:calorie ratio; however, the optimum ratio may differ between producers. The optimum lysine:calorie ratio will depend on whether the producer wants to formulate diets based on a philosophy to maximize performance (highest ADG or lowest F/G), minimize cost (lowest feed cost per unit of gain), or maximize profit (highest income over feed and facility cost).

Once SID lysine is determined, the ratios of other amino acids are set relative to lysine. Table 1 is an example of the minimum SID amino acid ratios relative to lysine. Most amino acid ratios are well-established; however, should be confirmed as growth potential of pigs continues to increase. Much of the disagreement between nutritionists in optimum ratios is a result of different amino acid loadings in diet formulation software. For example, a 68% valine to lysine ratio using amino acid data from one lab may be similar to a 70 or 72% ratio using data from another lab. A second disagreement in ideal ratios relative to lysine is differences in interpretation of the data. Optimal amino acid ratios are often depicted as a point using breakpoint analysis. In reality, a quadratic shape or diminishing returns model more accurately depicts the response to changing amino acid levels in most group feeding situations. Thus, a model can be used to determine whether the ratio will provide 99 or 95% of the maximum response.

This technique allows modeling of the ratio that provides the most economical response for a production system rather than simply the maximum res- ponse. Selecting the optimum amino acid ratio is dependent on the value of weight gain and increme- ntal cost to increase the ratio and therefore models allow for a more dynamic approach to setting the amino acid requirements of pigs. An example of advanced modeling techniques used to establish the optimum tryptophan level in the diet based on diet cost and value of the gain can be found at: https://www.asi.k-state.edu/research-and-extension/swine/calculators.html.

Table 1. Minimum ratios of other amino acids relative to lysine

	Weight range, kg				
	4 to 25	25 to 50	50 to 75	75 to 100	100 to 135
Isoleucine[a]	52	52	52	52	52
Leucine	100	100	100	100	100
Methionine & cysteine	56	56	56	57	58
Threonine	62	62	62	63	64
Tryptophan[a]	18	18	18	18	18
Valine[a]	68	68	68	68	68
Histidine	31	31	31	31	31

[a]Diets with high leucine (ex. > 140% of Lys) require higher isoleucine, tryptophan, and valine (Cemin, 2019).

The importance of correct ratios of essential amino acids to lysine is also based on the level of SID Lys that the diets are formulated to in relation to the requirement of the pigs. Clark et al. (2017) formulated nursery pig diets to SID Lys levels at or below the pigs estimated requirement and then within each level set the ratio of other essential amino acids to 1 of 3 levels: lower ratios typical of what a cost-focused commercial swine nutritionist may use, levels set to achieve 95% of maximum performance, or levels set to achieve maximum performance. Altering the ratios of essential amino acids to Lys when diets were formulated to the SID Lys requirement of the pigs had little impact on performance. However, when diets were formulated to SID Lys levels below the lysine requirement of the pigs, increased performance was observed as the ratio of essential amino acids to lysine was increased. In fact, pigs fed diets formulated to SID Lys below their requirement, but with essential amino acid to lysine ratios at levels to maximize performance resulted in overall ADG that was similar to those pigs fed the higher SID Lys diets. This study illustrated the value of feeding higher essential amino acid to lysine ratios when diets are formulated below the SID Lys requirement of the pig, which often times happens when reduced CP diets are formulated.

When formulating feed-grade amino acid supplemented low CP diets, it is important to ensure adequate quantities of nitrogen-containing compounds are available to support endogenous non-essential amino acid production. Millet et al. (2018) reported an SID Lys:CP ratio less than 0.0064% should be maintained to prevent reductions in performance due to reduced non-essential amino acid production. Utilizing this ratio in diet formulation, as opposed to a fixed CP minimum, is a better way to protect from non-essential deficiencies as the level of feed-grade amino acids increases in diets.

Reducing CP in nursery pig diets to reduce diarrhea

There is increased attention in nursery pig diet formulation to reduce CP considering existing and future regulations aimed to limit the amount of zinc oxide that can be utilized in swine diets. Pharmacological levels of zinc oxide are commonly utilized as a means to control post-weaning diarrhea (Højberg, 2005). Without these high levels of zinc oxide in the diets, excess nutrients, especially CP, will flow to the large intestine and lead to increased E. coli-related post-weaning diarrhea. A common way to minimize post-weaning diarrhea in the absence of zinc oxide is to increase the level of feed-grade amino acids included in the diets as a means to reduce CP. Batson et al. (2021) showed that increasing the level of feed-grade amino acids supplemented in diets and consequently reducing CP from 21% to 16.5% resulted in increased fecal dry matter as the level of CP was reduced. However, linear reductions in ADG and G:F were also observed with the greatest loss in performance occurring when CP fell below 19.5%. A significant amount of research continues to be conducted in early nursery diets to find ways to reduce post-weaning diarrhea in the absence of pharmacological zinc oxide and it is clear that a reduced CP, feed-grade amino acid fortified diet will be a fundamental part of future nursery diet formulation strategies.

One way to overcome any lost performance in early nursery diets due to reduced CP formulations is to take advantage of compensatory gain strategies. Nemechek (2018) conducted a trial where nursery pigs were fed diets in three phases and within each phase there was a low or high SID Lys (corresponding to low or high CP) treatment fed. Pigs that were fed low SID Lys in phase 1 and 2 (5.7 to 12 kg) and high SID Lys in phase 3 (12 to 20 kg) had the same ending weight as those fed high SID Lys throughout the study. This strategy of feeding lower CP, feed-grade amino acid fortified diets in early phases and maintaining higher amino acid levels in later nursery phases can help reduce the incidence of post-weaning diarrhea without loss of overall nursery performance.

Branched-chain amino acid relationships in finishing pig diets

In many parts of the world that rely on corn as the primary source of energy, a focus on formulating diets with low CP will result in a diet with reduced soybean meal and increased corn. This can create issues with amino acid imbalances because corn and corn by-products have elevated concentrations of leucine in relation to other amino acids. Harper (1984) showed that the branched-chain amino acids (BCAA), leucine, isoleucine, and valine, are structurally similar and share the first step of catabolism where an excess of any one of the BCAA can lead to the catabolism of the others with leucine appearing to be the most potent stimulator of catabolism. Additionally, Pardrige (1977) showed that BCAA and other large neutral amino acids (LNAA), such as tryptophan, share the same brain transporters and excesses of one can lead to competitive inhibition for absorption of others. Consequently, low CP diet formulation strategies that result in excesses of leucine relative to valine, isoleucine, and tryptophan may create imbalances of other amino acids and lead to less than optimal performance.

Cemin et al. (2019a) conducted a literature review and confirmed that relationships exist between individual BCAAs and tryptophan in regards to their influence on growth performance of pigs. A meta-regression analysis was conducted utilizing 44 trials and 210 different observations that resulted in prediction equations to optimize growth performance based on isoleucine, valine, and tryptophan concentrations in the diets containing higher concentrations of leucine (Cemin et al., 2019b).

The resulting prediction equation for ADG was:

ADG, g = – 985.94 + (15.2499 × average BW (kg)) – (0.08885 × average BW × average BW) + (1.063 × Leu:Lys) + (20.2659 × Ile:Lys) – (0.1479 × Ile:Lys × Ile:Lys) + (9.2243 × (Ile+Val):Leu) – (0.03321 × (Ile+Val):Leu × (Ile+-Val):Leu) – (0.4413 × Ile:Trp)

A trial was subsequently conducted to validate the prediction equation. Kerkaert et al. (2021) confirmed that performance was improved when high leucine diets were formulated to contain higher than normal levels of valine, isoleucine, or tryptophan. The Cemin et al.(2019b) equation predicted the growth performance that resulted from the added valine and isoleucine well with the equation over-predicting the response observed for increased tryptophan. Williams et al. (2021) conducted another trial and again confirmed that increasing the concentrations of isoleucine, valine, and tryptophan in diets formulated with high levels of leucine will improve performance, but also observed that excessively high levels of supplemental isoleucine, valine, and tryptophan will not further improve performance over the control. Collectively these data show that when formulating low CP, amino-acid fortified finishing pig diets, it is important to maintain optimum amino acid relationships, especially when high levels of leucine are also present.

Conclusions

Diet formulation strategies to reduce CP with feed-grade amino acid fortification will continue to be practiced in commercial swine production around the world. Low CP diet formulation can help reduce nitrogen excretion, reduce post-wean diarrhea, and reduce overall diet cost without negatively impacting pig performance as long as proper amino acid formulation techniques are implemented. New research demonstrating the relationship of BCAA and LNAA in diets containing high leucine has allowed for optimum growth performance of finishing pigs. Research will continue to explore ways to optimize low CP, feed-grade amino acid fortified diet formulation strategies to reach system production goals.

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