Opportunities in Utilizing Crystalline Amino Acids in Swine

Brian J. Kerr

National Swine Research and Information Center, USDA-ARS-SOMMRU, 2165 NSRIC Ames, IA, USA, 50011; ***Email:*** kerr@nsric.ars.usda.gov

■ Introduction

Amino acid nutrition of monogastrics has been investigated using individual amino acids since the discovery of threonine by W. C. Rose in 1935. With commercial availability of synthetic methionine (Met) and crystalline lysine (Lys) in the early 1960's, and because these two amino acids are typically first limiting in poultry and swine, respectively, there has been a plethora of research estimating their required needs. As additional crystalline amino acids became commercially available, tryptophan (Trp) and threonine (Thr) in the early 1980's, and isoleucine (Ile) and valine (Val) in the late 1990's, research on their estimated requirements and ratios relative to Lys has expanded our understanding on how to formulate diets to minimize amino acid excesses while meeting the nutritional needs of the animal. Research trials with these amino acids, however, are far fewer in number and often more variable than trials done with Met and Lys. Nevertheless, only through a comprehensive understanding of these next limiting amino acids in a diet can further progress in utilizing supplemental amino acids be made. High protein commodity prices [most notability the soybean meal (SBM) prices of 1973, 1977, 1988, and 2004], economically available alternative feed ingredients, and the increasing awareness of the impact of livestock production on the environment has further stimulated interest in feeding reduced protein, amino acid supplemented diets to swine and poultry. This review will focus on Trp, sulfur amino acids (SAA), Ile, Val, histidine (His), and leucine (Leu) trials in swine.

■ Tryptophan

The Trp requirement of pigs has been 'moderately' studied with requirement estimates varying between studies due to differences in dietary protein concentration, feedstuffs utilized, and ingredient digestibility. Recently a series of experiments by Guzik et al. (2002) determined the true digestible Trp requirement for nursery pigs. In the first set of trials, gelatin was utilized as a protein source deficient in Trp from which to conduct requirement assays. Data from that experiment suggested that in Phase I pigs (5 to 8 kg), the true digestible Trp requirement was 0.18, 0.19, and 0.16% for daily gain, feed efficiency, and plasma urea nitrogen, respectively. Due to the inability of pigs fed a gelatin-based diet to perform adequately in Phase II and III relative to pigs fed a positive control, subsequent trials utilized Canadian field peas. Data from those trials indicate that the true digestible Trp requirement was 0.21, 0.20, and 0.18% for pigs from 5 to 7, 6 to 10, and 10 to 16 kg, respectively. These data are in close agreement with current NRC (1998) recommendations.

Research on the Trp needs of growing pigs is limited. Recently, the University of Missouri and Louisiana State University have focused on Trp needs of growing-finishing pigs. Using serum urea nitrogen as a method to determine amino acid requirements, Guzik et al. (2005a) estimated the Trp needs of growing pigs fed a corn, SBM, Canadian field pea-based diet. For 31 kg pigs, serum urea nitrogen decreased as the digestible Trp content was increased from 0.13 to 0.21% with the broken-line regression analysis estimating the optimum digestible Trp requirement to be 0.167% (0.20% total Trp) to minimize serum urea nitrogen. As the digestible Trp content was increased from 0.09 to 0.17% in 51 kg pigs, broken-line analysis estimated the optimum digestible Trp requirement to be 0.134% (0.15% total Trp) to minimize serum urea nitrogen.

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Evaluation of Trp needs in finishing pigs is virtually nonexistent. In a corn, SBM, feather meal based-diet, Guzik et al. (2005a) reported that gain and feed efficiency increased linearly with the addition of Trp, while serum urea nitrogen decreased in a linear manner such that broken-line analysis estimated the digestible Trp requirement to be 0.094, 0.109 and 0.103%, respectively. The average of these values yields an estimate of 0.102% digestible Trp (0.12% total Trp) for optimal growth of finishing (75 to 105 kg) pigs. Additional work using a corn and feather meal-based diet with plasma urea nitrogen as the response criteria further estimated the digestible Trp requirement in 69 to 74 kg pigs to be 0.096%. These results are supported by researchers at the University of Missouri (Kendall et al., 2003) who demonstrated that the minimum true digestible Trp:Lys ratio for pigs from 90 to 125 kg was at least 0.145, but not greater than 0.17.

Compared to the NRC and North American diets, European diets tend to have higher Trp:Lys ratios. This is supported by van Cauwenberghe and

Relandeau (2000) who reported that 7 to 30 kg pigs fed a wheat, barley-based diet may need to have a 0.21 Trp:Lys ratio in their diet for optimal performance. Using corn, barley and pea based-diets, Eder et al. (2003) suggested that the standardized digestible Trp requirement for growing-finishing (25 to 115 kg) pigs may be higher than currently assumed. Consequently, an experiment was conducted in Canada utilizing typical European ingredients [diets contained barley, wheat, minimal amounts of corn, and no SBM] with 7 to 16 kg pigs fed diets varying in Trp:Lys and Thr:Lys ratios (Guzik et al., 2005b). Results from this experiment are perplexing because increasing the apparent digestible Thr:Lys ratio from 0.55 to 0.65 had little impact on performance, but there was a linear response to increasing the Trp:Lys ratio from 0.145 to 0.190. Based upon past research, one would have expected a response to the first level of Trp and not the second level of supplementation. In contrast, Warnants et al. (1998) showed no performance response in 7 to 20 kg pigs to additional Trp above 0.13% digestible Trp and no effect of supplementing Trp when dietary Thr appeared to be limiting, but improved gain and feed intake by increasing the Thr:Lys ratio to 0.65. The discrepancy in results between Warnants et al. (1998) and Guzik et al., 2005b) can not be explained, especially when these two experiments utilized a similar diet composition and used pigs of a similar weight range.

■ Methionine/Sulfur Amino Acids

An excellent review of research on SAA ratios for starter and growing pigs was presented by Peak (2005) at the 2005 Banff Pork Seminar. In that review, the requirement for SAA per unit of weight gain was relatively constant across trials, and when employing similar review methodology for Lys, the data suggested a 0.56 digestible SAA:Lys ratio. Because that review evaluated trials covering some time period, they also reported on trials recently conducted at the University of Missouri utilizing more modern, lean genotypes fed corn-soybean meal based diets. Data from these trials suggested that gain and feed efficiency were maximized with a SAA:Lys ratio between 0.60 and 0.62 (Gaines et al., 2004 abcd).

■ Isoleucine

> ***Crystalline Ile supplementation was clearly shown to overcome the performance depressing effects of SDBC***

Research evaluating Ile requirements of pigs is dated, sparse, and difficult to interpret. In an effort to evaluate Ile needs, scientists have utilized blood flour (Bringer et al., 1950; Becker et al., 1957, 1963; Bravo et al., 1970; Oestemer et al., 1973) or herring meal (Henry et al., 1976), while only four papers utilized more practical-type ingredients (Taylor et al., 1985; Bergstrom et al., 1997; Lenis and van Diepen, 1997; James et al., 2001b). The use of blood products has been used with uneasiness in the swine industry due to potentially poor palatability and amino acid availability. However, newer methods of processing have resulted in an increase in the usability of this product in swine feeding programs. Blood meal contains high levels of crude protein, Lys, and Val, but low concentrations of Ile and Met. Recently, several trials were undertaken using spray-dried blood cells (SDBC) as an Ile-deficient ingredient to evaluate Ile requirements of pigs. Spray-dried blood cells are a co-product of the porcine plasma production process and like blood meal, contain high concentrations of Leu, Lys, and Val, but a limited concentration of Ile. In starter (Kerr et al., 2004a), grower (Parr et al., 2003), and finisher (Parr et al, 2004) phases of growth, crystalline Ile supplementation was clearly shown to overcome the performance depressing effects of SDBC. Across all trials, these data indicate that SDBC can be supplemented at 7.5% in starter and grower pigs, and 5.0% in finishing pigs, and as long as Ile needs are met. Consequently, SDBC provides an excellent ingredient from which to evaluate Ile requirements and Ile:Lys ratios.

In starter pigs (7 to 11 kg), a corn-based diet containing 10.5% dried whey, 5% select fish meal, 6.75% SBM, and 7.5% SDBC was supplemented with graded levels to crystalline Ile to determine the Ile requirement (Exp. 1, 1.25% total Lys) or the Ile:Lys ratio (Exp. 2, 1.10% total Lys). Based on an average of all performance variables and plasma urea nitrogen, the digestible Ile requirement of 7 to 11 kg pigs was approximately 0.68% (0.68% in Exp. 1 and 0.67% in Exp. 2). Using a 1.10% digestible Lys diet which should be at or slightly below the digestible Lys requirement for these pigs, the digestible Ile:Lys ratio was determined to be 0.61, which is slightly higher than the current NRC (1998) requirement of 0.61% and Ile:Lys ratio of 0.59 (Kerr et al., 2004b).

In growing (25 to 45 kg) pigs, a corn-based diet containing 3.2% SBM and 7.5% SDBC with graded levels of crystalline Ile was utilized to determine the Ile requirement. The true digestible Ile requirement was determined to be 0.50% of the diet, or 1.46 g/Mcal of ME which is slightly higher than the 1.38 g/Mcal ME estimated by the 1998 NRC (Parr et al., 2003).

In finishing pigs, corn-based diets containing 5% SDBC as the protein source and incremental levels of crystalline Ile have been used to determine Ile requirements. Data from Parr et al. (2004) suggest that 0.31% true digestible Ile is required for high-lean late-finishing (87 to 100 kg) pigs, which is similar to the NRC (1998) factorial estimate of 0.83 to 1.01 g/Mcal ME for late-finishing barrows and gilts having a lean gain potential of 325 to 350 g/d. In contrast, Kendall et al. (2004a) reported a slightly higher requirement of 0.36% true digestible Ile for 91 to 117 kg barrows. Most recently, Dean et al. (2005) (81 to 115 kg) and Fu et al., (2005ab) (88 to 118 kg) confirmed that the Ile requirement in finishing pigs may be above the NRC estimate when SDBC are included in the diet, but in corn soybean meal diets the Ile requirement may be lower than current estimates.

Valine

Estimates of the Val requirements for pigs are almost nonexistent.

Demonstrating Val to be limiting in low protein diets has been a formidable task. In 20 kg pigs fed an 11% CP corn-SBM diet, Val appeared to be the fourth limiting amino acid when the diet was supplemented with Lys, Trp, and Thr (Russell et al., 1987) or possibly fifth limiting in diets supplemented with Lys, Trp, Met, and Thr (Figueroa et al., 2003). To complicate matters, in sorghum-soybean meal diets, Val may be third co-limiting with His, Ile, and Trp (Brudevold and Southern, 1994). Estimates of the Val requirements for pigs are almost nonexistent. Studies by Jackson et al. (1953) and Mitchell et al. (1968a) provided a Val baseline, but did not utilize pigs growing at rates typically noted today. Lewis and Nishimura (1995) estimated the Val requirement of 74 kg pigs to be approximately 0.50% of the diet. Since the 1998 NRC, five studies were found evaluating the Val needs of starting pigs. Mavromichalis et al. (2001) conducted a series of validation and digestibility studies and concluded that the Val requirement of 6 to 9 kg pigs was 0.86% or 2.50 g true digestible Val/Mcal ME, with 11 to 18 kg pigs having a Val requirement of 0.78% or 2.22 g true digestible Val/Mcal ME; each of these estimates being equal to or slightly higher than current NRC (1998) estimates. James et al. (2001a) utilized a corn, SBM, dried whey diet and determined that the true ileal digestible Val:Lys ratio was approximately 0.60 in 9 to 16 kg pigs. Warnants et al. (2001) estimated the requirement in Val in 8 to 21 kg pigs fed a corn, SBM, tapioca, barley, whey, and fish meal-based diet. Using graded levels of ideal protein where Val appeared to be the first limiting amino acid, the standardized ileal digestible Val requirement necessary to optimize gain and feed efficiency was 0.70% Val (0.75% apparent digestible Val), which equates to a standardized ileal digestible Val:Lys level of 0.68, similar to that suggested by the NRC (1998). Recently, Theil et al. (2004) suggested that maximal growth in 8 to 20 kg pigs was achieved at a digestible Val:Lys ratio of 0.72 while Kendall et al. (2004b) indicated the true Val:Lys ratio should be approximately 0.65 for 13 to 32 kg pigs.

▪ Histidine

Like Val, experimentation providing definitive information on the requirement of His in pigs is sparse. In 33 kg pigs, Fuller et al. (1979) provided data indicating that His may be the third-limiting amino acid in barley; in 20 kg pigs, Brudevold and Southern (1994) suggested that sorghum-soybean meal diets may be equally third limiting in His, Ile, Trp, and Val; while Figueroa et al. (2003) indicated that His (or Ile) may be the sixth-limiting amino acid in a corn-soybean meal, amino acid-fortified diet fed to 21 to 40 kg pigs.

Early research on His (Eggert et al., 1955; Mertz et al., 1955; Rechcigl et al., 1956) involved limited numbers of pigs and did not provide a practical basis to estimate the His requirement of pigs. Estimates by Kim et al. (1983) using an indicator amino acid method suggested a His requirement of approximately 0.4% total His (2 kg pigs) while nitrogen balance methods (Mitchell et al., 1968b) in 10 kg pigs suggested a total requirement of approximately 0.3% His. Using a corn-feather meal-whey basal diet, Izquierdo et al. (1988) estimated a bioavailable His requirement of the 10 to 20 kg pig to be 0.31% which equates to 0.36% total His in a corn-soybean meal diet.

▪ Leucine

Although practical diets contain an abundant amount of Leu, determination of Leu needs for pigs has importance due to potential imbalances and antagonisms between the other branched amino acids, Ile and Val (Kerr et al., 2004a). In general, it appears that except for purified or semi-purified diets, moderately large excesses of Leu have little to no impact on pig performance fed practical (Edmonds and Baker, 1987) or Ile-adequate (Parr 2003) diets. Only one paper has attempted to determine the amount of Leu deemed abundant in practical diets (Augspurger and Baker, 2004). Data reported in that experiment suggests that the true ileal digestible Leu requirement for 8 to 12 kg pigs is approximately 1.05%, equating to a Leu:Lys ratio of 1.0.

▪ Summary

Because of the increased availability of crystalline amino acids (Lys, Met, Thr, and Trp, including the 'new' amino acids Ile and Val), and the continual need to improve the utilization of nutrients to reduce the impact of livestock production on the environment (air, water, and soil), there is always a need to more fully understand amino acid nutrition of non-ruminants. In addition, characterization of ingredients or diets (total, apparent, standardized, or true, etc.), and method of data analysis (broken line, curvilinear, or exponential, etc.) still present a formidable task of summarizing published data into a concise data set for ultimate use in feed formulation. Lastly, determination of nutrient requirement estimates in older or heavier animals is costly and inherently variable such that substantial progress in refining their nutrient needs has been difficult. However, progress in understanding nutrient needs of these animals is vitally important since consumption of feed is greatest, and conversion efficiency into edible product is lowest, at these heavier weights.

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