

UPDATE: IDEAL AMINO ACID PROFILES FOR FINISHING PIGS

In 1998, the National Research Council (NRC, 1998) reviewed empirical evidence and published factorial estimates for the ideal ratios of amino acids to lysine for finishing pigs (Table 1). The NRC estimates were based on data from the Agricultural Research Council (ARC, 1981), Fuller and Wang (1990), Baker and Chung (1992), Cole and van Lunen (1994), and Baker (1997). A complete description of the data in these references can be found in Boisen et al. (2000).

Table 1. Ideal ratios of selected amino acids to lysine for finishing pigs (80 to 120 kg)

Amino acids	Maintenance	Protein accretion	Total/True	Apparent
Lysine	100	100	100	100
Methionine	28	27	27	28
Cystine	95	28	32	34
TSAA	123	55	59	62
Threonine	151	60	68	64
Tryptophan	26	18	18	17
Isoleucine	75	54	55	55
Valine	67	68	68	68

Adapted from NRC (1998).

Ratios for maintenance proposed by the NRC were based on work by Baker et al. (1966), Baker and Allee (1970), and Fuller et al. (1989). There are no recent data regarding amino acid requirements for maintenance of growing pigs. The ratios for protein accretion were derived from Fuller et al. (1989) and they were adjusted based on recent data from Professor D. H. Baker's work at the University of Illinois (Baker, 1997).

The present review examines information published after 1997 in an attempt to offer an update on the ideal amino acid profile for finishing pigs (80 to 120 kg). Only the ratios of the essential amino acids methionine (met), cystine (cys), threonine (thr), tryptophan (trp), isoleucine (ile), and valine (val) to lysine (lys) were considered because other amino acids will be in excess of optimal ratios to lysine in practical swine diets in the USA and abroad (Liu et al., 2000a,b).

Low-Protein Diets

The importance of accurate estimates of optimal amino acid ratio requirements emerges as the dietary protein concentration is reduced and crystalline amino acids are introduced to diet formulations. The order of limitation of amino acids in a particular diet usually determines the commercial amino acids that will be needed to maintain optimum balance of the essential amino

acids. In typical corn-soybean meal-based diets, lysine is first-limiting, with threonine, methionine, and tryptophan following as second, third, and fourth limiting, respectively (Russell et al., 1987; Mavromichalis et al., 1998; Johnston et al., 2000b). Beyond these amino acids, recent evidence indicates that isoleucine, valine, and perhaps histidine may become limiting as dietary protein concentration is reduced by more than 2 to 4 percentage points (Figuerola et al., 2000a,b).

Until recently, it was thought that dietary protein concentration could be safely reduced by at least 2 percentage points with no changes in either growth performance or carcass traits after appropriate fortification with crystalline amino acids. Reductions of more than 4 percentage points in dietary protein concentration yielded variable results, despite additions of appropriate amino acids. Several researchers reported that reduction of crude protein by 3 to 4 percentage points resulted in no changes in animal performance or carcass characteristics, whereas others reported fatter carcasses and slightly lower animal performance. This is believed to result, at least in part, because of increased dietary net energy. Nevertheless, reduction of dietary energy concentration in reduced-protein diets still did not always support equal performance. For comprehensive reviews of low-protein diets supplemented with crystalline amino acids refer to Kerr (1992 and 1996).

As dietary protein concentration is reduced, several unique concerns arise in corn-soybean meal-based diets. First, the balance between essential and non-essential amino acids is disturbed. This ratio should be around 50% to allow optimal nitrogen retention and utilization (Lenis et al., 1999). However, providing 1:1 non-protein nitrogen to low-protein diets fortified with crystalline amino acids does not maintain the same feed efficiency and carcass fatness compared with higher protein diets. Second, the importance of predicting lysine requirement increases because crystalline amino acids (which are expensive) are used proportionally to lysine. Third, with low-protein diets, it is often recommended that the net energy system be used (Noblet, 1995 and 1998) in conjunction with an amino acid matrix based on true rather than total or apparent ileal digestibilities (Boisen et al., 2000). Fourth, amino acid imbalances may develop if arginine becomes excessive compared to the lysine concentration, or leucine compared to the sum of isoleucine and valine concentrations (D'Mello, 1994). Fifth, sodium bicarbonate additions may be needed to buffer the acidic effect of excessive amounts of free amino acids. Obviously, a higher degree of accuracy in diet formulation is required.

Recently, Liu et al. (2000a,b) demonstrated that finishing pigs (86 to 114 kg) could be successfully raised on all-corn diets fortified with vitamins, minerals, and amino acids. Significant isoleucine and marginal valine additions were needed to allow the dietary crude protein concentration to fall from 13% (control) to 7% (a reduction of 6 percentage points). Isoleucine and valine appeared to be fifth and sixth limiting amino acids, respectively. It appears that with proper formulation, dietary crude protein concentration can be reduced by at least 3 percentage points with acceptable results.

Sulfur Amino Acids

The NRC (1998) recommends a ratio of 27 and 32% for methionine and cystine, respectively, to lysine on a total or true ileal digestible basis for finishing pigs. Hence, total sulfur amino acids (TSAA) should be provided at 59% of dietary lysine (Table 1). These values are in at least partial agreement with more recent data:

1. Knowles et al. (1997a,b) indicated that for growth and muscle traits, the optimum TSAA to lysine ratio may be closer to 50% in corn-cornstarch based diets, but it must be at least 58% to minimize fat accretion in 77 to 111 kg pigs.
2. Loughmiller et al. (1997) suggested that the TSAA to lysine ratio does not exceed 50% in 73 to 104 kg gilts, whereas the optimal methionine to lysine ratio was only 25%.
3. Johnston et al. (2000a) indicated an optimal ratio of TSAA to lysine of 54 to 57% for 54 to 84 kg pigs. Interestingly, the authors also noted that excess TSAA reduced feed efficiency without affecting body composition, an indication of significant cost in the metabolism of nitrogen.
4. Roth et al. (2000) suggested a 59% TSAA to lysine ratio as optimal for growth, and 53% for carcass characteristics in finishing pigs.

It appears that the NRC (1998) TSAA and methionine to lysine ratios may slightly overestimate actual requirements of modern lean, fast-growing pigs. Faster growing pigs, which require more lysine for growth than slower-growing pigs, have lower TSAA requirements as a proportion to lysine. Total sulfur amino acid needs apparently do not increase proportionally to lysine requirements as leanness increases because a significant fraction of the TSAA requirement is governed by maintenance requirements, and these remain constant as the lean-gain potential increases (Table 2). It is suggested, therefore, that the TSAA to lysine ratio be 55%, whereas the ratio of methionine to lysine should not exceed 25% for finishing pigs (80 to 120 kg) when growth and carcass characteristics are considered jointly (Table 3).

Table 2. Effect of protein deposition rate on TSAA to lysine ratio for finisher pigs (80 to 120 kg)

	Protein accretion = 120 g/d		Protein accretion = 200 g/d	
	Lysine	TSAA	Lysine	TSAA
Maintenance	1.14	1.43	1.14	1.43
Protein deposition	<u>14.40</u>	<u>7.92</u>	<u>24.00</u>	<u>13.20</u>
Total requirement	15.54	9.35	25.14	14.63
Ratio (TSAA:lysine)	60		58	

Based on calculations from NRC (1998).

Threonine

The NRC (1998) recommends a 68% ratio of threonine to lysine on a total or true ileal digestible basis for finishing pigs. This value, however, is not in agreement with more recent data:

1. Kerr (2000) reviewed the literature (trials conducted between 1977 and 1997) and calculated that the optimal threonine to lysine ratio to be between 58% (averaging across trials) and 62% (using individual point estimates) for 75-kg pigs.
2. Schutte et al. (1997) indicated that pigs between 50 and 95 kg body weight require no more than 0.45% true ileal digestible threonine, which corresponds to about 64% of the digestible lysine requirement (i.e., 0.70%).

3. Rademacher et al. (1997) suggested that finishing pigs (60 to 100 kg) require, on average, 0.36% true ileal digestible dietary threonine, corresponding to a 51% ratio to lysine.
4. Cadogan et al. (1998) indicated that finishing pigs (60 to 100 kg) require at least 0.49% total threonine (70% of lysine).
5. Li et al. (1998) suggested that growing pigs require a 68% ratio of threonine to lysine to optimize growth performance.
6. Lorsch and Patience (1999a) calculated the digestible threonine requirement for protein deposition to be 5.42 g/100 g protein deposited. Taking into account the corresponding lysine requirement of 8.98 g/100 g, they estimated a threonine to lysine ratio of 60%.
7. Frank et al. (2001) evaluated threonine to lysine ratios that ranged from 55 to 70% and indicated that finishing gilts (90 kg) do not require more than 65% threonine to lysine.
8. Johnston et al. (2001) also indicated that the optimum threonine:lysine ratio is 68% for gilts and barrows from 90 to 120 kg body weight.

It appears that estimates for optimal threonine to lysine ratio are variable, ranging from 51 to 70%, with a mean of 64%. Nevertheless, there is considerable evidence to suggest the optimal ratio may be lower than currently thought, but more research is needed to clarify this issue.

Tryptophan

The NRC (1998) recommends a ratio of tryptophan to lysine of 18% on a total or true ileal digestible basis for finishing pigs. Like TSAA and threonine, the tryptophan to lysine ratio increases with increasing body weight because the ratio is greater for maintenance than growth (Table 1). Also, these amino acids have a faster turnover rate from tissue pools than lysine. This ratio, however, does not agree with more recent data:

1. Lorsch and Patience (1999b) calculated the digestible tryptophan requirement for protein deposition to be 1.68 g/100 g protein deposited. Taking into account the corresponding lysine requirement of 8.98 g/100 g, they estimated a tryptophan to lysine ratio of 19%.
2. Castaing (1999) indicated the optimal tryptophan to lysine ratio was 20 to 21% for finishing pigs.
3. Peisker (2000) demonstrated that about 0.15% total tryptophan is required by finishing pigs (67-105 kg), which corresponds to 21% of total lysine.

Taking into account (1) the difficulties associated with chemical analysis of tryptophan and (2) recent evidence with weanling swine that indicates a required ratio between 19 and 22%, it is suggested that the NRC (1998) ratio for tryptophan for finishing requires further investigation.

Branched-chain amino acids

No recent data exist for the required ratio of branched-chain amino acids to lysine. Valine and isoleucine appear to become limiting as dietary crude protein is reduced by more than 4 percentage points. Valine is more limiting than isoleucine in diets for growing pigs, whereas in finishing pigs, isoleucine is more limiting than valine. Recent evidence (Mavromichalis, 2001) indicates that the estimate of the valine requirement for nursery pigs by the NRC (1998) may not reflect the higher requirements of modern-type swine. Liu et al. (2000b) demonstrated, however, that 52-kg barrows do not need more than 11.4 g/d true digestible valine, indicating that current NRC ratios for valine may be correct for growing-finishing pigs. Parr et al. (2001) suggested that the NRC (1998) isoleucine requirement estimates might be adequate for finishing pigs. Until more data become available, valine and isoleucine ratios presented in Table 1 should be used as a guideline for diet formulation (Table 3).

Table 3. Updated ratios of selected amino acids to lysine for finishing pigs (80 to 120 kg) based on recent research reports (1997-2000)

Amino acids	Total/true
Lysine	100
Methionine	25
Cystine	30
TSAA	55
Threonine	64
Tryptophan	20
Isoleucine	55
Valine	68

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