Recent Developments in Nutritional Programs for Wean-to-Finish Pigs

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1. Introduction

Technology adoption has allowed for dramatic improvements in, wean-to-finish growth performance over the last 35 years. In 1980, the average market weight was 110 kg with pigs having more than 25 mm of fat at the 10^{th} rib, and produced less than 35 kg of lean meat from the carcass (National Pork Board, 2016). Growth performance records from 1980 are scarce; however, in 1990, pigs grew at 575 g/day and had a 3.2:1 feed efficiency from weaning to market (PigChamp, 1990).

By comparison, todays' average pig has a wean-to-finish average daily gain of 730 g/day and a feed conversion of 2.6:1 (National Pork Board, 2016). The average market weight is now 128 kg with 18 mm of backfat and a pig now produces more than 54 kg of lean meat. This has allowed for a 38% increase in pork production with only a 10% increase in the annual number of animals harvested over the same time period (USDA-NASS, 2015). While certainly genetics has played a huge role in these improvements, a solid nutrition program is critical to allow todays' pig to express their true genetic potential. Under these circumstances, nutrition programs are evolving to meet the lean growth requirements of the pig, but also produce pork in an economical fashion.

2. Weaner Pig Diets

We know that dietary lysine is extremely important in weanling pig diets. Over the years, we have changed our philosophy on formulating weaner pig diet formulations to lower lysine and crude protein concentrations than those used in the past. Nemecheck et al. (2010) demonstrated we could achieve similar growth performance by feeding early weaner pig diets formulated to 1.40 to 1.35% standardized ileal digestible (SID) lysine in phase 1 and 2 diets compared to the 1.60 and 1.55 SID lysine used in the past. However, with the low lysine program it is essential to keep the 10 to 20 kg pig diets at a relatively high dietary lysine concentration of 1.35%. The ramifications of this strategy is that with the ability to formulate the first 2 diets fed post weaning to a low lysine level (again maintaining adequate lysine levels in phase 3), we don’t need as much of the specialty protein sources, hence saving diet cost.

2.1 Other Amino Acids

With digestible lysine levels set, we have now turned our attention to the other limiting amino acids because of the greater availability and economics of using more feed-grade amino acids. Given that lysine levels may still vary slightly from one farm to the next, it is preferred to express requirements for other amino acids as a ratio relative to lysine. Goncalves et al. (2015) and more recently Clark et al.

(2017) have determined the ideal ratios for tryptophan, isoleucine and valine relative to lysine. However, the unique aspect of these findings is the use of new statistical modelling techniques to determine the dose-response to the individual amino acids. By doing so, we can determine a requirement for maximizing growth and feed conversion, but also develop a model that predicts the change in a response criteria (i.e., average daily gain) if different ratios of the amino acid relative to lysine are selected. Using these techniques, a nutritionist and producer can evaluate the feed-grade amino acid's cost, and the impact on gain to select a ratio possible lower than the one to maximize growth based on the farm's specific production goals and economics (Table 1).

Table 1. Suggested amino acid:lysine ratios for different levels of growth performance from weaning to 25 kg[1]

Amino acid	95% of maximum performance	100% of maximum performance
Methionine	28	30
Methionine & Cysteine	56	60
Threonine	62	65
Tryptophan	19	21
Valine	67	72
Isoleucine	52	52

[1] Adapted from Goncalves et al. (2015), Clark et al. (2017a, 2017b).

3. Grow-finish Pigs

Because of continued increases in average daily gain and improvements in feed efficiency, SID lysine concentrations continue to increase. Recently we compared our standard recommendations to new proposed industry lysine estimates

(Menegat et al., 2017). In this study, 4 dietary feeding regiments were evaluated (Table 2). The first treatment was a 4-phase feeding regimen designed to maximize growth. The second treatment was our current specifications designed to maximize income over feed costs in a 4-phase feeding regimen. The third regimen was our standard diets early in phases 1 and 2, followed by maximum concentrations in phases 3 and 4. The last treatment was a simple 2-phase feeding regimen. As expected the pigs on the maximum regimen had excellent growth performance throughout the study and, while not statistically significant, had greater market weight and slightly greater income over feed cost (IOFC) compared with the standard regimen. What is interesting to note was that pigs fed the standard followed by the maximum diets or even the two phase regimen were equally as profitable. It appears that pigs fed slightly below their ideal lysine requirement early in the growing phase, had compensatory gain in later finishing providing that lysine was adequate. Overall, results suggest that feeding lysine levels for maximum growth and efficiency in either a 2- or 4-phase feeding program results in the same growth performance and feed cost and that a broad range of lysine specifications within the levels tested herein can be utilized in grow-finish diets without compromising income over feed cost.

Table 2. Description of feeding phases and lysine levels of experimental diets[1,2]

Phase	1				2				3				4			
Duration, d	0 to 25				25 to 53				53 to 81				81 to 117			
Weight range, kg	27 to 50				50 to 73				73 to 100				100 to 127			
	MAX	STD	STD/ MAX	2- Phase	MAX	STD	STD/ MAX	2- Phase	MAX	STD	STD/ MAX	2- Phase	MAX	STD	STD/ MAX	2- Phase
SID Lys, %	1.13	1.02	1.02	0.96	0.96	0.87	0.87	0.96	0.82	0.76	0.82	0.96	0.77	0.67	0.77	0.77
SID Lys:ME, g/Mcal	3.42	3.08	3.08	2.89	2.89	2.62	2.62	2.89	2.46	2.28	2.46	2.89	2.29	1.99	2.29	2.29
SID Lys:NE, g/Mcal	4.61	4.12	4.12	3.84	3.84	3.46	3.46	3.84	3.24	2.98	3.24	3.84	3.00	2.59	3.00	3.00

[1] Dietary treatments were: MAX, a 4-phase feeding program with lysine levels for maximum growth; STD, a standard 4-phase feeding program for optimal IOFC; STD/MAX, a 4-phase feeding program based on standard lysine levels in early finishing and for maximum growth in late finishing; and 2-PHASE, a 2-phase feeding program.

[2] The equations used for lysine requirement estimates for finishing gilts in g/Mcal NE were: 0.00006 ´ BW^2, lb - 0.0291 ´ BW, lb + 6.6894 for maximum growth (PIC, 2016);

Table 3. Effect of phase feeding strategies using different lysine specifications on growth performance and economics of grow-finish pigs[1,2,3]

Item	MAX	STD	STD/MAX	2-PHASE	Probability, $P <$
BW, kg					
d 0	27.9	27.9	27.9	27.9	0.998
d 25	49.4[a]	49.0[ab]	48.4[bc]	48.0[c]	0.002
d 53	73.8	72.7	72.5	73.4	0.208
d 81	100.1[ab]	98.3[b]	99.5[ab]	100.9[a]	0.029
d 117	129.7	127.1	129.4	129.8	0.109
d 0 to 25					
ADG, kg	0.86[a]	0.84[a]	0.83[ab]	0.80[b]	0.001
ADFI, kg	1.65[a]	1.65[a]	1.63[a]	1.57[b]	0.001
F/G	1.93[b]	1.95[ab]	1.99[a]	1.96[ab]	0.063
d 25 to 53					
ADG, kg	0.87[ab]	0.85[b]	0.85[b]	0.90[a]	0.005
ADFI, kg	2.12	2.09	2.09	2.07	0.364
F/G	2.44[a]	2.47[a]	2.45[a]	2.29[b]	< 0.001
d 53 to 81					
ADG, kg	0.93[bc]	0.91[c]	0.95[ab]	0.97[a]	0.001
ADFI, kg	2.58	2.53	2.57	2.62	0.192
F/G	2.79[a]	2.78[ab]	2.70[bc]	2.68[c]	0.003
d 81 to 117					
ADG, kg	0.85	0.83	0.85	0.84	0.463
ADFI, kg	2.69[ab]	2.63[b]	2.72[ab]	2.75[a]	0.051
F/G	3.16	3.20	3.20	3.28	0.296
d 0 to 117					
ADG, kg	0.88[ab]	0.85[b]	0.87[ab]	0.88[a]	0.048
ADFI, kg	2.29	2.26	2.28	2.29	0.514
F/G	2.62	2.64	2.63	2.60	0.193
Economics					
Feed cost $ per pig[4]	47.99[b]	45.38[c]	47.05[b]	48.23[b]	< 0.001
Feed cost per kg gain[5]	0.468[b]	0.454[c]	0.463[b]	0.470[b]	0.001
Revenue[6]	113.07	110.80	112.77	113.65	0.183
IOFC[7]	65.08[ab]	65.42[ab]	65.72[a]	65.43[ab]	0.039

[1] A total of 1,188 pigs (PIC 359 × 1050; initially 27 kg BW) were used with 27 pigs per pen and 11 pens per treatment.
[2] Dietary treatments were: MAX, a 4-phase feeding program with lysine levels for maximum growth; STD, a standard 4-phase feeding program for optimal IOFC; STD/MAX, a 4-phase feeding program based on standard lysine levels in early finishing and for maximum growth in late finishing; and 2-PHASE, a 2-phase feeding program.
[3] Means with different superscripts are significantly different (P < 0.05) in the row.
[4] Corn was valued at $3.30/bu ($118/ton), soybean meal at $290/ton, DDGS at $94/ton, and L-lysine at $0.75/lb.
[5] Feed cost per lb gain = feed cost per pig ÷ overall gain per pig.
[6] Revenue = (HCW × $0.70) – (d 0 BW × 0.75 × $0.70).
[7] Income over feed cost = revenue – feed cost.

Table 4. Effects of standardized total tract digestible (STTD) P on nursery pig growth performance[1]

Item	STTD P, %[2]								Probability, $P <$	
	0.26	0.30	0.33	0.38	0.43	0.48	0.53			
% of NRC (2012)[3]	80	90	100	115	130	145	160	SEM	Linear	Quadratic
d 0 to 21										
ADG, kg	0.51	0.51	0.53	0.53	0.57	0.56	0.57	0.026	0.001	0.718
ADFI, kg	0.78	0.76	0.78	0.78	0.82	0.83	0.83	0.043	0.001	0.603
F/G	1.52	1.50	1.46	1.47	1.45	1.46	1.45	0.015	0.001	0.067
Economics, $										
Feed cost/pig	3.88	3.81	3.88	3.93	4.15	4.20	4.25	0.098	0.001	0.589
Feed cost/kg gain[2]	0.36	0.36	0.35	0.35	0.35	0.36	0.35	0.0017	0.451	0.049
Total revenue/pig[3,4]	11.14	11.07	11.58	11.56	12.29	12.23	12.44	0.251	0.001	0.718
IOFC[5]	7.26	7.26	7.69	7.62	8.14	8.03	8.19	0.168	0.001	0.408

[1] A total of 1,080 barrows and gilts (PIC; 337 × Camborough, initial pen average BW of 11.5 kg) were used in a 21-d growth trial with 23 to 27 pigs per pen and 6 pens per treatment. Two groups of pigs were weaned at approximately 21 d of age, fed a common phase 1 and phase 2 diet for 21 or 24 d post-weaning, then fed experimental diets.

[2] Low (0.26% STTD P) and high (0.53% STTD P) diets were blended at the farm by a robotic feeding system to create the 0.30, 0.33, 0.38, 0.43, and 0.48% STTD P dietary treatments.

[3] The NRC (2012) requirement estimate for nursery pigs from 11 to 25 kg, expressed as a percentage of the diet, is 0.33% STTD P. Therefore, treatment concentrations represented 80, 90, 100, 115, 130, 145, and 160% of the NRC (2012) requirement.

Table 5. Standardized total tract digestible (STTD) P requirement for nursery and growing-finishing pigs[1,2]

	Body weight range, kg						
Item	11-27	27-36	36-54	54-73	73-91	91-113	113-131
Avg BW, kg	17	30	45	60	80	100	120
Diet NE, Kcal/kg	2,410	2,430	2,430	2,496	2,540	2,545	2,545
STTD P	0.43	0.40	0.36	0.32	0.29	0.27	0.25
STTD P:NE	3.93	3.63	3.27	2.83	2.52	2.34	2.17

[1] Phosphorus specifications are based on the data generated in the present trial and a STTD P nursery phase 3 trial; thus, 130% of the NRC (2012) requirements was used for the nursery phase 3, and 122% of the NRC (2012) for growing-finishing phases 1, 2, 3, and 4.

[2] The regression equation is: STTD P = 0.0000020072 × (body weight, kg × 2.2046)^2 – 0.0014032410 × (body weight, kg × 2.2046) + 0.4816400603.

3.1 Phosphorus Requirements

Another important nutrient from growth, and more importantly an environmental standpoint, is phosphorus (P). The NRC (2012) adopted the concept of standardized total tract digestibility (STTD) to report the requirements for P, which are based on modeled estimates vs those derived from actual performance studies. The NRC (2012) emphasized a need for actual studies to validate the model-derived digestible P requirement. In two studies, one with 10 to 20 kg pigs and the other from 25 to 130 kg, it appears that indeed STTD P requirements are greater than NRC (2012) projections based as a percentage of the diet. However, results of these studies are comparable to NRC (2012) estimates when expressed as a grams per day basis. Given that lower feed intake occurs in commercial production environments compared to NRC (2102), modeled feed intake P requirement estimates need to be increased on a percentage of the diet. The estimated STTD P requirement for finishing pigs from 25 to 130 kg ranged from 116 to 131% of the NRC (2012) requirement estimates for each phase, depending on the response criteria and statistical model. Again, applying the modelling techniques used in the previous amino acid studies, an economic evaluation can be made based on diet costs and the need to maximize growth performance or bone strength.

4. Conclusions

While nutrient requirements change over time with improved genetics and production practices, the basics of formulating to a farm's specific conditions still apply. First, based on the systems goals, determine the ideal energy density of the diet. Then, based on energy concentration, select lysine and phosphorus levels based on a nutrient:calorie ratio. Third, balance other amino acids relative to lysine. With application of new statistical modelling techniques to determine ideal nutrient concentrations, pork producers with their consultants can determine the most economical formulation strategy and feeding regimen for their farm.

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