Effects of Feeding Varied Levels of Balanced Protein on Growth Performance and Carcass Composition of Growing and Finishing Pigs[1,2]

N. W. Shelton, J. K. Htoo[3], M. Redshaw[3], R. D. Goodband, M. D. Tokach, S. S. Dritz[4], J. L. Nelssen, and J. M. DeRouchey

Summary
A total of 1,003 barrows and gilts (PIC 337 × 1050, initially 113.5 lb) were used in an 88-d study to determine effects of various levels of balanced amino acid density on growth performance and carcass characteristics. Balanced amino acid refers to balancing the dietary amino acids according to the ideal protein ratio, at least for the first 4 limiting amino acids; the other amino acids may be at or higher than required levels. In this study, this balance was accomplished by using supplemental amino acids and formulating to meet the first 4 limiting amino acids: lysine, threonine, methionine, and tryptophan. Three experimental diets were tested using 6 replicate gilt and 7 replicate barrow pens per treatment. These diets were tested over 2 different phases, a grower phase (d 0 to 28) and a finishing phase (d 28 to 88). Dietary treatments included a diet that met the NRC (1998)[5] requirements, a diet that met Evonik Degussa (Hanau, Germany) requirements, and a diet that was formulated to be 10% greater than Evonik Degussa recommendations. No gender × dietary treatment interactions were observed ($P > 0.30$) for any of the growth or carcass characteristics. During the growing phase, ADG and F/G improved (linear; $P < 0.03$) as amino acid density increased in the diet. Also, gilts had decreased ($P < 0.001$) ADFI and improved ($P < 0.001$) F/G from d 0 to 28 compared with barrows. During the finishing phase, no differences were observed ($P > 0.62$) in ADG, ADFI, or F/G from increasing dietary lysine or balanced protein levels. Gilts had decreased ($P < 0.001$) ADG and ADFI compared with barrows. Over the entire 88-d trial, F/G improved (linear; $P < 0.04$) and a trend was detected for improved (linear; $P < 0.06$) ADG as dietary amino acid density increased. No dietary treatment differences were observed ($P > 0.28$) for carcass yield, backfat depth, loin depth, percentage lean, live value, or calculated income over feed cost. In this experiment, increasing the amino acid density (dietary lysine level) over the NRC (1998) requirement offered improvements in the grower phase but not the finishing phase.

Key words: amino acid, lysine

Introduction
A current emphasis in the pork industry is to maximize lean growth in pigs through genetic selection and proper nutrition. Maximum lean growth can be achieved only when nutrients, specifically amino acids and energy, are supplied in the diet at the

[1] Appreciation is expressed to New Horizon Farms for the use of pigs and facilities and to Richard Brobjorg, Scott Heidebrink, and Marty Heintz for technical assistance.
[2] The authors thank Evonik Degussa for partial funding of this project.
[3] Evonik Degussa GmbH, Rodenbacher Chaussee 4, 63457 Hanau, Germany.
[4] Food Animal Health and Management Center, College of Veterinary Medicine, Kansas State University.
[5] NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

appropriate amount. Amino acid requirements can be influenced by many factors, including dietary protein level, dietary energy density, environmental temperature, sex, and lean growth potential of the pig. Lysine is the first limiting amino acid in most practical swine diets. It is a common practice to first define the adequate lysine level in the diet and then derive the required level of other essential amino acids from lysine on the basis of an ideal protein ratio, thus giving a balanced protein diet. A balanced protein diet contains sufficient levels of each essential amino acid to meet the biological needs of the animal while minimizing the amounts of excess amino acids.

Some recent studies have suggested that the dietary lysine requirements for pigs with high genetic potential for lean gain are higher than the NRC (1998) estimated requirement values. For example, Main et al. (2002[6]) reported that the optimal total lysine:ME ratio for maximizing growth parameters in 130- to 190-lb gilts was 2.80 g/Mcal. In addition, Shelton et al. (2008[7]) observed improvements in ADG and F/G up through 2.55 g SID lysine/Mcal ME in 185- to 245-lb gilts. Therefore, it is important to evaluate the optimal level of balanced amino acids in the diet to maximize the rate and efficiency of pig lean tissue growth and carcass quality of modern high lean growth pigs.

Procedures

Procedures in this experiment were approved by the Kansas State University Institutional Animal Care and Use Committee. The experiment was conducted at a commercial research finishing facility in southwestern Minnesota. The facility was double curtain sided with completely slatted flooring. Pens were 10 × 18 ft and were equipped with a 5-hole conventional dry feeder and a cup waterer.

Pigs (PIC 337 × 1050) were moved to the finisher at approximately 60 lb and placed into single-sex pens with 27 pigs per pen. Pens were randomly allotted to a gender treatment prior to the arrival of the pigs. Pigs were fed standard grower diets that were adequate in all nutrients (NRC, 1998) for approximately 5 wk until the beginning of the trial.

A total of 1,003 barrows and gilts (initially 113.5 lb) were then selected and used in an 88-d study to determine effects of various levels of balanced amino acid density on growth performance and carcass characteristics. Three experimental diets were tested using 6 replicates (pens) of gilts and 7 pens of barrows per treatment. Experimental diets were allotted to gender-specific pens in a completely randomized design, and initial weight was equalized across dietary treatments within gender.

Three experimental diets with different amino acid densities were tested for the growing phase (d 0 to 28; approximately 120 to 170 lb BW) and the finishing phase (d 28 to 88; approximately 170 to 280 lb BW; Table 1). The low diet was formulated to contain the dietary amino acid content according to the NRC (1998) requirements. The moderate diet was formulated to the current recommendations of Evonik Degussa (Hanau, Germany). The high diet was formulated to be 10% greater than the moderate diet. All diets within each phase contained similar NE concentrations. The total and standardized

[6] Main et al., Swine Day 2002, Report of Progress 897, pp. 135-150.

[7] Shelton et al., Swine Day 2008, Report of Progress 1001, pp. 82-92.

ileal digestible (SID) amino acid values of ingredients were based on the AminoDat 3.0 database in diet formulation.

Pig weights (by pen) and feed disappearance were measured throughout the trials. On the basis of these measurements, ADG, ADFI, and F/G were calculated for each pen. At the conclusion of the growth portion of the trial, the majority of the pigs were marketed to a USDA-inspected packing plant, and carcass data were collected. Any pigs weighing less than 200 lb (n = 15 head) were removed and not included in the market data. Pen data for yield, backfat depth, loin depth, and percentage lean were determined by the packing plant. Yield reflects the percentage of HCW in the live weight (obtained at the packing plant). Live value, feed cost per pound of gain, and income over feed cost (IOFC) were also calculated. Live value was determined by taking a base carcass price $61.45, adding lean premiums, subtracting discounts, and converting to a live weight basis. Income over feed cost was determined on a per head basis by taking the full value for each pig and subtracting the feed costs incurred during the trial.

Data were then analyzed as a 2 × 3 factorial design (2 genders and 3 dietary treatments) using the PROC MIXED procedure in SAS (SAS Institute Inc., Cary, NC). Dietary lysine values were used as dose levels to test for linear and quadratic responses to dietary treatments. Pen was used as the experimental unit in all analyses.

Results and Discussion

Analyzed amino acid levels for the major ingredients and diets are shown in Table 2. Ingredient samples reflect the mean of 4 subsamples that were analyzed using near-infrared spectroscopy. Diet samples reflect means of 2 subsamples that were analyzed utilizing wet chemistry amino acid analysis. Formulated diet values are included in parenthesis. The analyzed diet levels coincided with formulated values.

No gender × dietary treatment interactions were observed ($P > 0.30$, Table 3) for any of the growth or carcass characteristics. During the growing phase (d 0 to 28), ADG and F/G improved (linear; $P < 0.03$) as amino acid density increased in the diet. The most advantageous values were seen in the high treatment, indicating that the lysine requirement is greater than current NRC (1998) requirement estimates. Gilts had lower ADFI and better F/G ($P < 0.001$) than barrows.

During the finishing phase (d 28 to 88), no dietary treatment differences were observed ($P > 0.62$) for ADG, ADFI, or F/G, indicating that the low amino acid density diet was adequate to meet the requirement of the finishing pigs in this study. However, the analyzed total lysine content (0.65%) in the finisher diets was about 8% higher than the NRC (1998) recommendation of 0.60%. Gilts had decreased ($P < 0.001$) ADG and ADFI compared with barrows. Despite the lack of response in the finishing phase, F/G improved (linear; $P < 0.04$) and ADG tended to increase (linear; $P < 0.06$) over the entire 88-d trial as amino acid density increased in the diets. In both barrow and gilt treatments, the most beneficial values were seen in the high treatment. Overall, gilts also had decreased ($P < 0.001$) ADG and ADFI and improved ($P < 0.01$) F/G in compared with barrows.

Similar to the finishing phase growth data, no dietary treatment differences were observed ($P > 0.28$) for carcass yield, backfat depth, loin depth, percentage lean, live value, or IOFC. Feed cost per pound of gain increased (linear; $P < 0.004$) as dietary amino acid density increased, which was not surprising because the improvements in feed efficiency were not substantial enough to offset the added diet cost. In addition, gilts had improved ($P < 0.02$) backfat depth, loin depth, and percentage lean figures compared with barrows. These improvements in carcass composition resulted in increases ($P < 0.001$) in the live value and IOFC of the gilts. Also, the improvement in F/G for gilts resulted in improved ($P < 0.01$) feed cost per pound of gain.

Lysine requirement studies have been conducted with this genetic line (PIC 337 × 1050) in these facilities by Main et al. (2002) and Shelton et al. (2008). The ADG and F/G responses to the SID lysine:ME ratio for the grower portion of the current study are compared with responses in the earlier studies in Figures 1 and 2, respectively. Both the Main et al. (2002) and Shelton et al. (2008) studies showed the impact of increasing SID lysine:calorie ratio for gilts. The present study shows lower pig growth performance than the earlier studies; however, the requirement of 2.58 g SID lysine/Mcal ME seen by Shelton et al. (2008) matches the improvements found through the high level (2.62 g SID lysine/Mcal ME) in this study.

The ADG and F/G responses for the finishing portion of this study are compared with results of several earlier trials in Figures 3 and 4, respectively. All weight categories were not similar for all studies. Therefore, a variety of weights groups were graphed in each figure. Figure 3 shows that ADG for pigs fed the lowest lysine level in this trial (NRC requirement) was similar to the ADG in Shelton et al. (2008). However, improvements in gain due to increasing dietary lysine were seen in the earlier study, but no benefits were observed in the present study. As seen from Figure 4, F/G showed a similar pattern; Shelton et al. (2008) showed benefits to feeding lysine levels higher than the NRC (1998) requirement, but the present study showed no benefit. This raises questions as to the difference in response between trials. The present study used different formulation techniques than the earlier trials. Also, diets in this trial had much lower energy levels than diets used by Shelton et al. (2008) and Main et al. (2002), with 3% and 6% added fat, respectively. The difference in fat levels helps explain the overall increase in F/G in the present trial. Feed efficiency results from this portion of the trial are similar to responses seen by Main et al. (2002), in that for 170- to 225-lb and 220- to 265-lb gilts, only a slightly higher response was determined above the NRC (1998) requirement.

This study indicates that in the grower stage, feeding diets with higher lysine levels than previously recommended can improve gains and efficiency. In the finishing stage, however, the NRC (1998) recommendations were adequate to meet the biological needs of the animal for growth and conversion of feed to lean tissue.

Table 1. Diet composition and calculated analysis (as-fed basis)

	Growing phase (d 0 to 28)			Finishing phase (d 28 to 88)		
Ingredient, %	Low[1]	Moderate[2]	High[3]	Low[1]	Moderate[2]	High[3]
Corn	80.04	78.25	72.65	82.23	78.74	73.90
Soybean meal	17.40	18.65	23.30	15.60	18.75	22.76
Biolys[4]	0.12	0.36	0.31	---	0.16	0.11
DL-Methionine	---	0.08	0.09	---	0.03	0.05
L-Threonine	---	0.06	0.05	---	0.03	0.02
L-Tryptophan	---	0.01	0.01	---	---	---
Choice white grease	0.09	0.25	1.31	---	0.15	1.06
Monocalcium P	0.96	0.95	0.92	0.87	0.85	0.83
Limestone	0.95	0.95	0.92	0.87	0.86	0.84
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix	0.09	0.09	0.09	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
Standardized ileal digestible (SID) amino acids, %						
Lysine	0.66	0.81	0.89	0.55	0.71	0.78
Isoleucine:lysine	76	64	66	85	74	74
Leucine:lysine	183	152	149	213	175	169
Methionine:lysine	32	36	37	38	35	35
Met & Cys:lysine	64	63	63	74	65	65
Threonine:lysine	70	65	65	78	70	70
Tryptophan:lysine	20	19	19	22	19	20
Valine:lysine	88	75	75	100	85	86
CP, %	14.54	15.23	16.93	13.78	15.13	16.6
Total Lys, %	0.76	0.92	1.00	0.66	0.82	0.90
ME, kcal/lb	1,512	1,518	1,539	1,513	1,518	1,532
NE, kcal/lb	1,084	1,084	1,084	1,084	1,084	1,084
SID lysine:ME, g/Mcal	1.98	2.42	2.62	1.65	2.12	2.31
SID lysine:NE, g/Mcal	2.76	3.39	3.72	2.30	2.97	3.26
Total Ca, %	0.60	0.60	0.60	0.55	0.55	0.55
Available P, %	0.25	0.25	0.25	0.23	0.23	0.23
Diet cost, $/ton[5]	269.02	284.25	294.49	264.85	273.96	284.03

[1] Low = NRC (1998) requirement estimates.
[2] Moderate = Evonik Degussa recommendations.
[3] High = 10% greater than Diet 2.
[4] Biolys contains 50.7% L-Lys (Evonik Degussa GmbH, Hanau, Germany).
[5] Prices based on June 2008 (Informa economics).

Table 2. Chemical composition of ingredients and diets

	Ingredients		Grower diets			Finisher diets		
Item, %[1]	Corn	Soybean meal	Low[2]	Moderate[3]	High[4]	Low[2]	Moderate[3]	High[4]
CP	7.0	46.4	13.8 (14.5)	13.9 (15.3)	16.6 (17.0)	12.8 (13.8)	14.1 (15.1)	15.8 (16.6)
Arginine	0.34	3.36	0.85	0.87	1.00	0.79	0.86	1.00
Histidine	0.20	1.26	0.37	0.38	0.42	0.36	0.38	0.43
Isoleucine	0.24	2.08	0.58	0.59	0.65	0.53	0.57	0.66
Leucine	0.84	3.49	1.31	1.34	1.41	1.24	1.28	1.39
Lysine	0.23	2.83	0.75 (0.76)	0.86 (0.92)	1.01 (1.01)	0.65 (0.66)	0.78 (0.82)	0.89 (0.90)
Methionine	0.14	0.64	0.23 (0.24)	0.29 (0.32)	0.34 (0.36)	0.22 (0.23)	0.26 (0.28)	0.31 (0.31)
Met + Cys	0.29	1.33	0.47 (0.50)	0.53 (0.59)	0.61 (0.64)	0.46 (0.47)	0.52 (0.54)	0.57 (0.59)
Phenylalanine	0.35	2.32	0.69	0.71	0.78	0.64	0.68	0.77
Threonine	0.25	1.83	0.54 (0.55)	0.57 (0.62)	0.65 (0.68)	0.50 (0.52)	0.55 (0.59)	0.62 (0.65)
Tryptophan	0.06	0.64	0.16 (0.16)	0.17 (0.18)	0.20 (0.20)	0.15 (0.15)	0.16 (0.17)	0.19 (0.19)
Valine	0.33	2.22	0.67	0.68	0.74	0.62	0.66	0.74
Alanine	---	---	0.77	0.79	0.83	0.73	0.76	0.82
Aspartic acid	---	---	1.35	1.38	1.57	1.23	1.35	1.56
Cysteine	0.15	0.69	0.24	0.25	0.27	0.24	0.25	0.27
Glutamic acid	---	---	2.50	2.55	2.81	2.34	2.48	2.80
Glycine	---	---	0.56	0.58	0.64	0.53	0.57	0.65
Proline	---	---	0.91	0.92	0.97	0.87	0.90	0.97
Serine	---	---	0.67	0.68	0.77	0.63	0.67	0.76

Values in parentheses represent calculated values.
[1] Ingredients means were based on 4 subsamples from various ingredient batches with analysis by near-infrared spectroscopy, and diet samples reflect the means of 2 samples from different diet batches and were analyzed by wet chemistry amino acid analysis.
[2] Low = NRC (1998) requirement estimates.
[3] Moderate = Evonik Degussa recommendations.
[4] High = 10% greater than Diet 2.

Table 3. Effects of feeding various levels of balanced protein density on growth and carcass composition of growing and finishing pigs[1]

	Barrow			Gilt				Probability, *P*				
								Gender ×			Lysine	
Dietary treatment:[2]	Low	Moderate	High	Low	Moderate	High	SEM	Lysine	Gender	Lysine	Linear	Quadratic
Initial wt, lb	113.9	113.7	113.9	113.2	113.2	113.2	1.17	0.99	0.50	0.99	0.99	0.92
d 0 to 28												
ADG, lb	1.96	1.98	2.16	1.93	2.01	2.03	0.061	0.41	0.32	0.06	0.03	0.34
ADFI, lb	5.30	5.26	5.31	4.95	5.01	4.78	0.117	0.45	0.001	0.67	0.57	0.53
F/G	2.71	2.66	2.46	2.57	2.50	2.36	0.048	0.80	0.001	0.001	0.001	0.03
Intermediate wt, lb	169.9	170.0	174.4	168.7	169.7	169.9	2.12	0.57	0.24	0.35	0.22	0.44
d 28 to 88												
ADG, lb	1.91	1.87	1.91	1.72	1.76	1.76	0.036	0.49	0.001	0.86	0.63	0.78
ADFI, lb	6.35	6.30	6.45	5.74	5.81	5.71	0.113	0.56	0.001	0.95	0.75	0.91
F/G	3.34	3.38	3.38	3.34	3.29	3.26	0.062	0.56	0.18	0.97	0.82	0.88
Final wt, lb	278.9	283.6	285.3	268.5	272.3	272.9	2.53	0.93	0.001	0.09	0.03	0.77
d 0 to 88												
ADG, lb	1.92	1.91	1.99	1.79	1.84	1.85	0.030	0.31	0.001	0.11	0.06	0.37
ADFI, lb	6.00	5.94	6.07	5.47	5.54	5.40	0.103	0.42	0.001	0.99	0.98	0.93
F/G	3.12	3.12	3.05	3.06	3.01	2.93	0.044	0.77	0.01	0.07	0.04	0.27
Carcass measurements												
Yield, %[3]	74.97	74.91	74.74	75.00	75.03	75.06	0.427	0.95	0.65	0.98	0.86	0.91
Backfat depth, in.	0.82	0.84	0.82	0.68	0.67	0.66	0.02	0.77	0.001	0.75	0.61	0.57
Loin depth, in.	2.40	2.41	2.45	2.47	2.56	2.49	0.042	0.43	0.02	0.47	0.29	0.53
Lean, %	53.5	53.3	53.7	55.9	56.3	56.3	0.388	0.67	0.001	0.71	0.43	0.80
Live value, $/cwt[4]	45.69	45.53	46.13	47.27	47.85	47.70	0.459	0.65	0.001	0.62	0.35	0.84
Feed cost/lb gain, $[5]	0.42	0.43	0.44	0.41	0.42	0.42	0.006	0.73	0.01	0.02	0.004	0.82
IOFC, $/head[5,6]	56.99	56.43	54.72	62.76	62.62	61.74	1.93	0.95	0.001	0.66	0.43	0.66

[1] A total of 1,003 barrows and gilts (PIC 337 × 1050) were housed at 27 pigs/pen with 7 barrow and 6 gilt replications per lysine level in an 88-d trial.
[2] Low = NRC (1998) requirement (0.66% SID lysine in the first period and 0.55% in the second); Moderate = Evonik Degussa recommendations (0.81% SID lysine in the first period and 0.71% in the second); and High = 10% above Degussa recommendations (0.88% SID lysine in the first period and 0.78% in the second).
[3] Yield is expressed in terms of the amount of weight in the hot carcass in relation to the live weight obtained at the abattoir.
[4] Value was determined by using a base carcass price of $61.45, adding premiums, and subtracting discounts.
[5] Feed prices are based on June 2008 (Informa economics).
[6] Income over feed costs = value per head - feed costs during trial period.

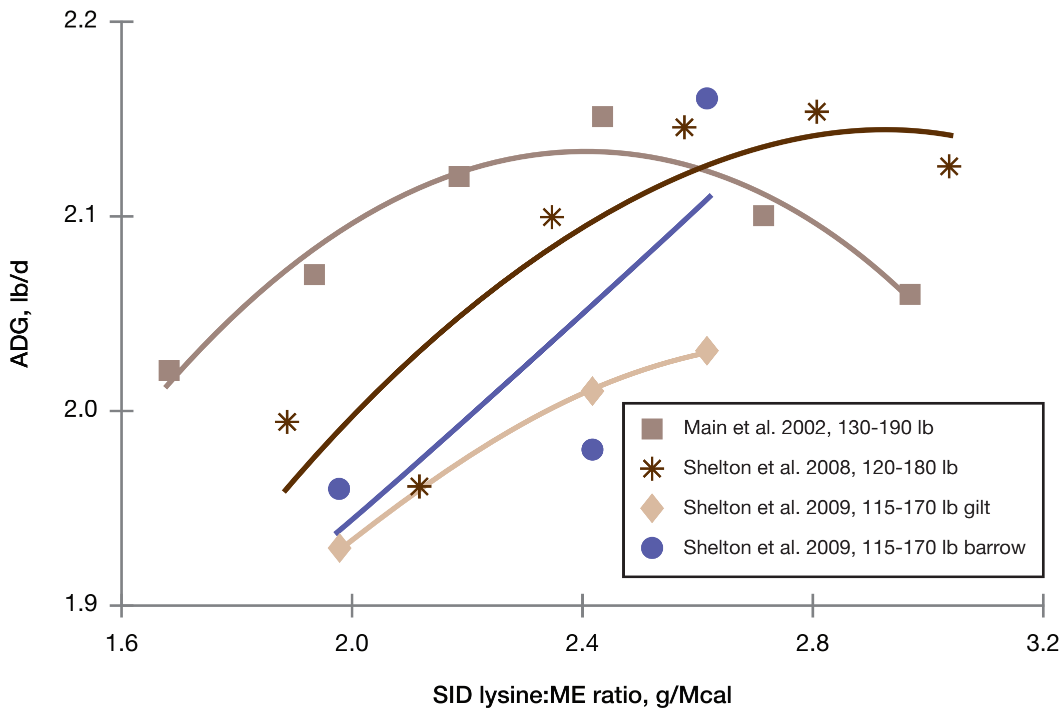

Figure 1. Comparisons of ADG response in relation to SID lysine:calorie ratio from several studies with similar pig weights.

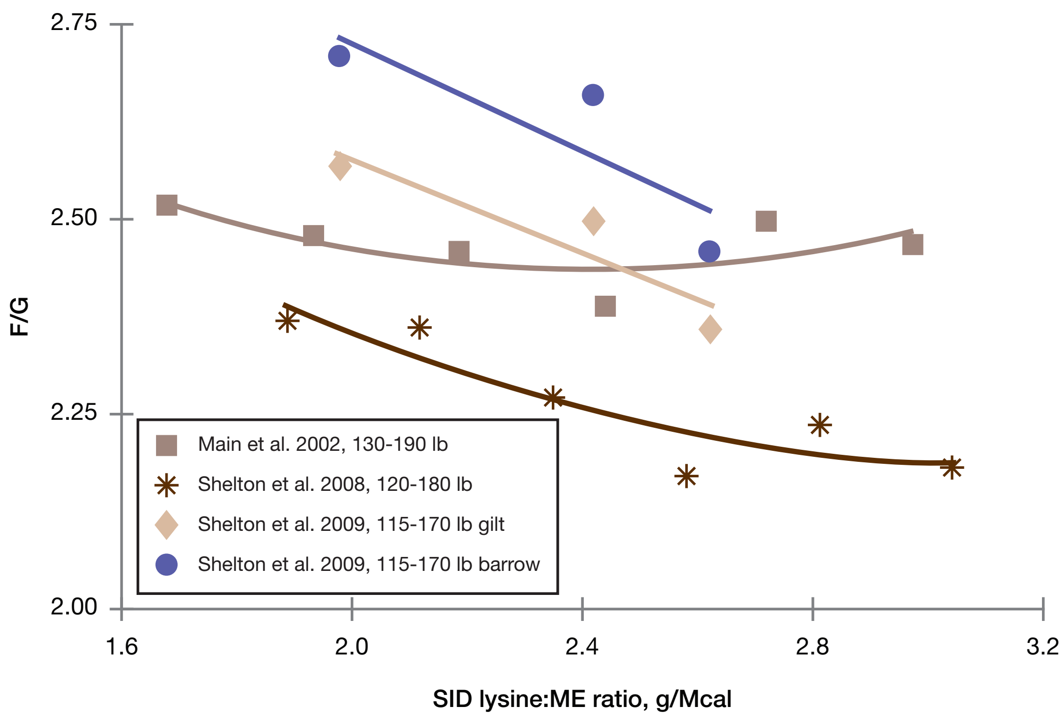

Figure 2. Comparisons of F/G response in relation to dietary SID lysine:calorie ratio from several studies with similar pig weights.

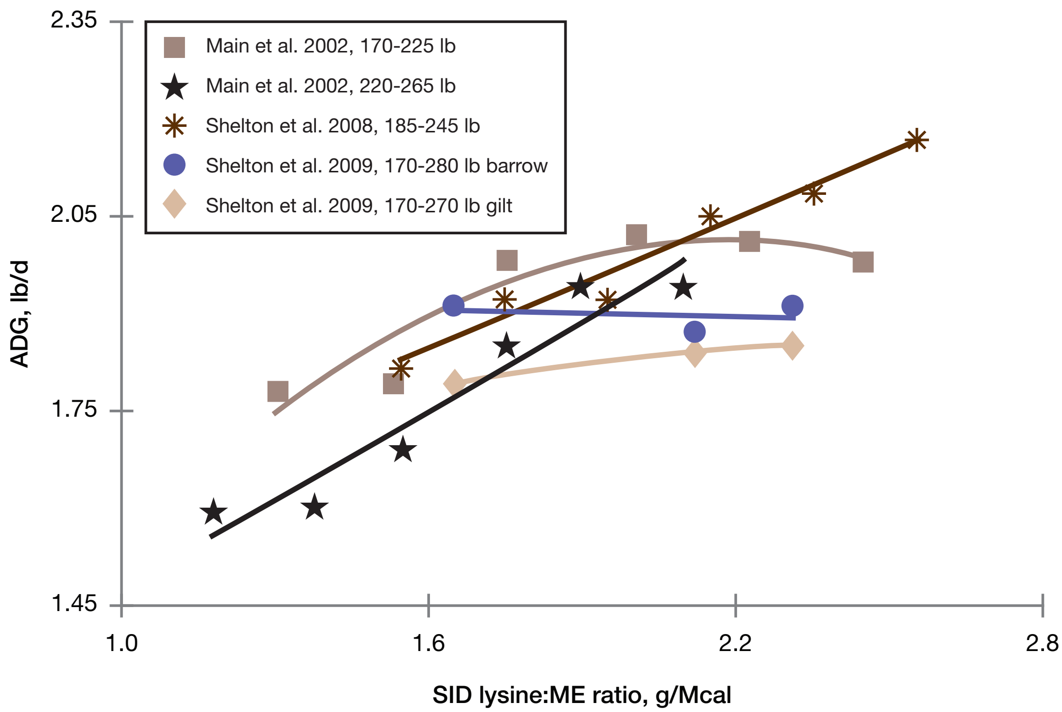

Figure 3. Comparisons of ADG response in relation to dietary SID lysine:calorie ratio from several studies with similar pig weights.

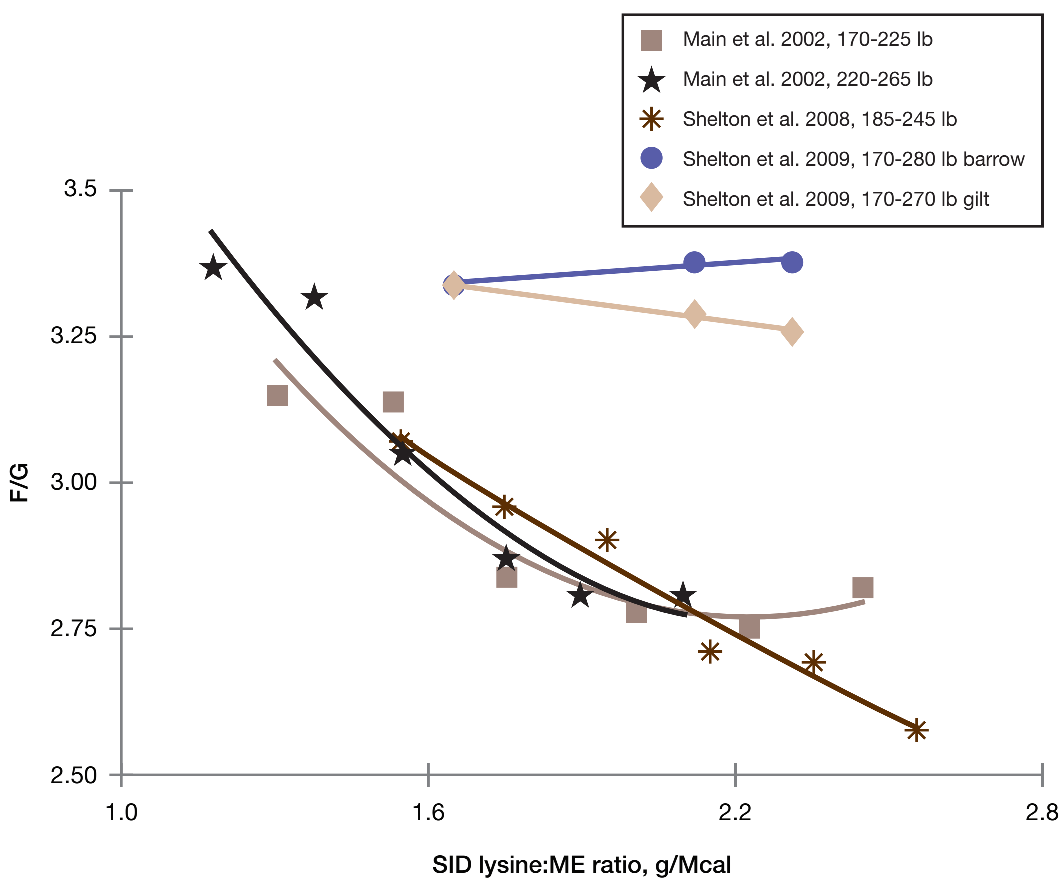

Figure 4. Comparisons of F/G response in relation to dietary SID lysine:calorie ratio from several studies with similar pig weights.