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January 2005

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Effect of Increasing Dietary Crude Protein Concentration on Growth Performance and Serum Insulin-Like Growth Factor-I Concentration in Barrows and Gilts

Robert L. Fischer
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Summary and Implications

A study was conducted to investigate the effects of increasing dietary protein intake on growth performance, carcass composition and serum insulin-like growth factor-I (IGF-I) concentration in growing-finishing barrows and gilts. Seventy crossbred pigs (35 barrows and 35 gilts) with an initial body weight of 75.1 lb were used in a 26-day growth study. The pigs were allocated randomly to one of four dietary treatments. The diets were standard corn soybean meal diets, which were formulated to contain 10, 14, 18, or 22% crude protein by changing the ratio of corn to soybean meal in the diet. At the termination of the experiment, pigs were slaughtered to determine carcass accretion rates of protein, water, fat and ash. Pig and feeder weights were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI), and calculation of feed efficiency (ADG/ADFI). Weekly blood samples were collected to evaluate dietary effects on plasma urea and IGF-I concentrations. There was no difference (P > 0.10) in ADFI among treatments; however barrows consumed more feed than gilts (3.94 versus 3.70 lb/d; P = 0.01) throughout the 26-day period. Dietary protein concentration had linear and quadratic effects on ADG and ADG/ADFI (P < 0.01). Also, barrows gained weight faster (ADG: 1.57 versus 1.41 lb; P < 0.01) and were more efficient (ADG/ADFI: 0.40 versus 0.38 lb/lb; P = 0.02) than gilts throughout the experiment. Increased dietary protein concentration resulted in increased fat-free lean gain, cold carcass weight (linear, P < 0.01; quadratic, P < 0.01) and dressing percentage (quadratic effect, P < 0.01). Protein concentration had a linear effect (P < 0.01) on plasma urea during weeks 1 through 4 and had a quadratic effect (P < 0.01) during weeks 1 and 4 of the experiment. Also, dietary crude protein concentration had linear and quadratic effects (P < 0.01) on serum IGF-I concentrations during weeks 2 and 4 of the experiment. In summary, dietary protein concentration had linear and quadratic effects on final body weight, ADG, feed efficiency, fat-free lean gain, cold carcass weight, plasma urea and serum IGF-I concentration. Thus, the interesting finding in this experiment was that the decrease in fat-free lean gain and protein accretion rate in pigs fed the 18% CP diet were not associated with a decrease in serum IGF-I concentration. This finding suggests that nutritional and (or) physiological factors are inhibiting the actions of IGF-I by causing a decrease in protein accre-

Table 1. Ingredient and chemical composition of diets, as-fed basis.

	Dietary protein concentration, %			
Item	10	14	18	22
Ingredient, %				
Corn	89.10	79.00	69.10	59.00
Soybean meal, 46.5% CP	5.50	15.75	25.75	36.00
Tallow	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.05	1.00	0.95	0.85
Limestone	0.70	0.65	0.58	0.55
Salt	0.30	0.30	0.30	0.30
Vitamin premix[a]	0.20	0.20	0.20	0.20
Mineral premix[b]	0.15	0.15	0.15	0.15
Analyzed nutrient composition				
Crude protein, %	10.72	13.79	17.39	21.93
Dry matter, %	89.71	89.41	89.84	89.77
Calcium, %	0.60	0.71	0.60	0.68
Total phosphorus, %	0.48	0.59	0.53	0.66
Crude fat, %	5.24	5.29	5.21	5.16
Calculated nutrient composition				
Lysine, %	0.39	0.65	0.90	1.16
ME, Mcal/lb[c]	1.57	1.57	1.57	1.57

[a]Supplied per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 440 IU; α-tocopherol acetate, 24 IU; menadione sodium bisulfite, 3.5 mg; riboflavin, 8.8 mg; d-pantothenic acid, 17.6 mg; niacin, 26.4 mg; vitamin B_{12}, 26.4 µg.
[b]Supplied per kilogram of diet: Zn (as ZnO), 128 mg; Fe (as $FeSO_4 \cdot H_2O$),128 mg; Mn (as MnO), 30 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$), 0.26 mg; Se (as Na_2SeO_3), 0.3 mg.
[c]Metabolizable energy.

tion rate. Thus, the future focus of this research is to determine the effects of dietary crude protein and crystalline amino acids on serum IGF-I concentration and metabolic actions.

Introduction

Excessive excretion of nitrogen by livestock operations is a major environmental concern. A consequence of excess nitrogen excretion is the potential for leaching of nitrates into groundwater and from runoff of nitrates into surface water. Thus, a major factor that has stimulated interest in the use of low-protein amino-acid supplemented diets is the potential positive impact on the environment. It is estimated that when growing-finishing pigs are fed low-protein amino acid-supplemented diets there is a 30% reduction in nitrogen excretion. Nutritional and hormonal factors are major determinants of animal growth, but the mechanisms of how protein (amino acids) influence the hormonal control of protein accretion in growing animals remains relatively undefined. Protein accretion in growing animals is mediated indirectly by pituitary growth hormone. When growth hormone is bound to specific receptors, it stimulates the production of insulin-like growth factor-I (IGF-I). Although growth hormone is the primary stimulus for IGF-I synthesis, many nutritional factors (i.e., protein intake, energy intake and essential amino acid intake) affect the production and action of IGF-I in the growing animal. Therefore, the current research seeks to augment the current knowledge of how the use of crystalline amino acids affects protein accretion by gaining a greater understanding of how IGF-I is affected by dietary concentrations of crude protein (amino acids) in swine growing-finishing diets.

The long-range goal of this research is to determine the concentrations of essential amino acids and the dietary protein ingredient (protein-bound versus crystalline amino acids) that will optimize IGF-I expression in growing-finishing pigs to maximize protein accretion. The objective of this experiment was to demonstrate *in vivo* the effect of increasing dietary protein intake on serum IGF-I concentration in barrows and gilts.

Procedures

Animals and treatments

Seventy crossbred [Danbred × (Danbred × NE White Line)] barrows and gilts were used in a 26-day growth study. Pigs averaged 75.1 and 114.0 lb at the initiation and termination of the experiment, respectively. Three barrows and three gilts were selected randomly for an initial slaughter group in order to collect tissue samples and determination of carcass composition. The remaining 64 pigs (32 barrows and 32 gilts) were assigned randomly to one of four dietary treatments. Diets (Table 1) were standard corn soybean meal diets and formulated to contain 10, 14, 18, or 22% crude protein (CP) by changing the ratio of corn to soybean meal in the diet. Diets were fortified with vitamins and minerals to meet or exceed NRC (1998) requirements for 45-lb pigs. Pigs were housed in an environmentally controlled building and allowed ad libitum access to feed and water throughout the experiment.

Data and sample collections

Pig and feeder weights were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI), and calculation of feed efficiency (ADG/ADFI). Fat-free lean gain (FFLG) was calculated using the National Pork Producers Council (2000) equations. Initial fat-free lean was estimated using initial body weight and final fat-free lean was calculated

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Table 2. Effect of protein concentration on growth performance of growing barrows and gilts.

Item	Dietary protein concentration, %				SEM	P-Value				
	10	14	18	22		Trt	Sex	Trt x Sex	Linear	Quadratic
Total number of pigs	16	16	16	16						
Barrows	8	8	8	8						
Gilts		8	8	8	8					
Growth performance										
Initial wt., lb	75.17	75.61	74.93	74.71	0.510	NS	NS	NS	NS	NS
Barrows	76.18	74.93	74.71	74.51	0.721					
Gilts	74.18	76.29	75.15	74.88	0.721					
Final wt., lb	99.31	113.07	119.69	123.92	1.296	< 0.01	< 0.01	NS	< 0.01	< 0.01
Barrows	101.50	114.75	120.83	126.92	1.819					
Gilts	97.15	111.37	118.54	120.90	1.819					
d 0 to 26 ADG, lb [a]	0.93	1.43	1.72	1.89	0.044	< 0.01	< 0.01	NS	< 0.01	< 0.01
Barrows	0.97	1.52	1.76	2.01	0.064					
Gilts	0.88	1.35	1.68	1.76	0.064					
ADFI , lb [b]	3.64	3.92	3.81	3.92	0.097	NS	0.01	NS	NS	NS
Barrows	3.84	4.12	3.90	3.97	0.137					
Gilts	3.44	3.75	3.73	3.88	0.137					
ADG/ADFI	0.25	0.37	0.45	0.48	0.007	< 0.01	0.02	0.05	< 0.01	< 0.01
Barrows	0.25	0.37	0.45	0.51	0.010					
Gilts	0.26	0.36	0.45	0.46	0.010					

[a]ADG = average daily gain.
[b]ADFI = average daily feed intake.

Table 3. Effect of protein concentration on ultrasound and carcass measurements of growing barrows and gilts.

Item	Dietary protein concentration, %				SEM	P-Value				
	10	14	18	22		Trt	Sex	Trt x Sex	Linear	Quadratic
Total number of pigs	16	16	16	16						
Barrows	8	8	8	8						
Gilts	8	8	8	8						
Ultrasound measurements (day 26)										
Backfat, in	0.49	0.48	0.48	0.44	0.018	NS	NS	NS	NS	NS
Barrows	0.51	0.49	0.50	0.44	0.027					
Gilts	0.48	0.46	0.45	0.45	0.027					
LMA, in^2 [a]	2.64	3.21	3.51	3.59	0.082	< 0.01	NS	NS	< 0.01	< 0.01
Barrows	2.58	3.19	3.40	3.50	0.116					
Gilts	2.69	3.24	3.62	3.68	0.116					
FFLG, lb/d [b c]	0.33	0.60	0.75	0.84	0.020	< 0.01	NS	NS	< 0.01	< 0.01
Barrows	0.31	0.62	0.73	0.87	0.028					
Gilts	0.34	0.59	0.77	0.82	0.028					
Carcass measurements										
Hot carcass wt., lb	69.57	80.28	86.79	88.00	.858	< 0.01	0.01	NS	< 0.01	< 0.01
Barrows	71.02	81.14	87.16	89.72	1.211					
Gilts	68.11	79.40	86.41	86.28	1.211					
Cold carcass wt., lb	67.52	77.26	83.48	84.65	0.964	< 0.01	< 0.01	NS	< 0.01	< 0.01
Barrows	68.93	78.43	84.36	86.74	1.360					
Gilts	66.11	76.12	82.62	82.56	1.360					
Dressing, %	69.71	69.88	70.99	69.24	0.325	< 0.01	< 0.05	NS	NS	< 0.01
Barrows	69.55	69.37	70.59	68.96	0.458					
Gilts	69.87	70.38	71.39	69.53	0.458					
Liver, lb	1.70	1.89	2.12	2.40	0.050	< 0.01	0.01	NS	< 0.01	NS
Barrows	1.77	1.94	2.16	2.49	0.071					
Gilts	1.63	1.84	2.07	2.31	0.071					

[a]LMA = longissimus muscle area.
[b]FFLG = fat-free lean gain.
[c]Calculated using equations derived from NPPC, 2000.

Table 4. Effect of protein concentration on carcass accretion rates of growing barrows and gilts.

	Dietary protein concentration, %					P-Value				
Item	10	14	18	22	SEM	Trt	Sex	Trt x Sex	Linear	Quadratic
Total number of pigs	16	16	16	16						
Barrows	8	8	8	8						
Gilts	8	8	8	8						
Empty body weight, lb	95.34	110.07	117.64	121.63	1.213	< 0.01	< 0.01	NS	< 0.01	< 0.01
Barrows	97.51	111.75	118.89	124.08	1.711					
Gilts	93.21	108.38	116.38	119.20	1.711					
Protein, g/d	41.80	82.70	104.96	119.95	2.671	< 0.01	NS	< 0.05	< 0.01	< 0.01
Barrows	42.02	85.92	101.98	128.24	3.778					
Gilts	41.57	79.47	107.93	111.67	3.778					
Fat, g/d	163.32	160.46	168.88	141.73	10.725	NS	NS	NS	NS	NS
Barrows	179.20	155.89	185.30	137.45	15.167					
Gilts	147.45	165.02	152.46	146.02	15.167					
Water, g/d	130.25	243.26	322.47	351.05	8.745	< 0.01	0.02	NS	< 0.01	< 0.01
Barrows	135.36	258.23	320.25	377.07	12.368					
Gilts	125.14	228.29	324.69	325.03	12.368					
Ash, g/d	8.27	11.24	10.81	12.50	0.891	0.01	NS	0.05	< 0.01	NS
Barrows	7.91	12.38	10.58	15.31	0.891					
Gilts	8.65	10.10	11.03	9.69	1.259					

using real-time ultrasound backfat and longissimus muscle area collected on day 26 of the experiment. Plasma urea and serum insulin-like growth factor-I (IGF-I) concentrations were determined in blood collected weekly throughout the experiment.

Statistical analysis

Data were analyzed as a completely randomized design using PROC MIXED of SAS (1999). The main effects in the statistical model were dietary protein concentration (10, 14, 18, and 22% CP) and sex. In all analyses, pig was the experimental unit. Only linear and quadratic effects are presented for variables in which the main effect of CP was significant (P < 0.05).

Results and Discussion

Growth performance

The response of ADG, ADFI, and ADG/ADFI to dietary treatments is shown in Table 2. There was no difference (P > 0.10) in ADFI among treatments; however, barrows consumed more feed than gilts (3.94 versus 3.70 lb/d; P = 0.01) throughout the 26-day experimental period. Protein concentration had linear and quadratic effects on ADG and feed efficiency (P < 0.01). Average daily gain increased as the dietary crude protein concentration increased from 10% (0.93 lb/d) to 22% (1.89 lb/d; a 49% improvement in gain). Feed efficiency responded similarly as ADG. Pigs fed the 10% dietary CP had the lowest ADG/ADFI (0.25) and pigs fed the diet containing 22% CP had the greatest ADG/ADFI (0.48; a 52% improvement in feed efficiency). Barrows gained weight faster (1.57 versus 1.41 lb/d; P < 0.01) and were more efficient (0.40 versus 0.38 lb/lb; P = 0.02) than gilts throughout the experiment.

Carcass characteristics

Real-time ultrasound measurements recorded on day 26 are summarized in Table 3. At the end of the experiment, there were no crude protein (dietary treatments) or sex effects on backfat (BF) depth; however, crude protein concentration resulted in linear and quadratic effects (P < 0.01) on ultrasound longissimus muscle area (LMA). Longissimus muscle area was similar among pigs fed diets containing 18 and 22% CP (3.51, 3.59 in^2, respectively); however, pigs fed the 10 and 14% dietary CP had a reduction in LMA (3.21 and 2.64 in^2, respectively). Protein concentration had linear and quadratic effects on fat-free lean gain (P < 0.01). Pigs fed the 22% CP diet had the greatest fat-free lean accretion rate (0.84 lb/d). Increased dietary protein concentration resulted in increased hot and cold carcass weights (linear and quadratic, P < 0.01) and a quadratic effect (P < 0.01) in carcass dressing percentage. Barrows had greater hot (82.3 versus 80.0 lb) and cold (79.6 versus 77.0 lb) carcass weights than gilts. Gilts had a greater (P < 0.05) carcass dressing percentage than barrows (70.3 versus 69.6%). Increased crude protein concentration linearly affected (P < 0.01) liver weight. Barrows had heavier liver weights (2.09 lb) than gilts (1.96 lb), which was apparently a result of greater ADFI of barrows. There were no differences (P > 0.10) in the other internal organ weights (i.e. heart, lungs, spleen, stom-

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ach, small intestine, large intestine, and mesentery) among dietary treatments and between barrows and gilts (data not shown).

Carcass accretion rate

The effect of dietary protein concentration on carcass accretion rates in growing barrows and gilts are shown in Table 4. Dietary protein concentration had linear and quadratic effects on empty body weight and protein and water accretion rates (P < 0.01). Empty body weight increased as the dietary concentration of crude protein increased from 10% (95.3 lb) to 22% dietary CP (121.6 lb). Barrows had greater (P < 0.01) empty body weights than gilts (113.1 versus 109.4 lb). Protein accretion rates increased from 41.8 g/d in pigs fed the 10% CP diet to 120 g/d in pigs fed the 22% CP diet. This increase in protein accretion rate is supported by the increase in water accretion rates as dietary protein concentration increased. The greater protein and water accretion rates in pigs fed the diets with a greater concentration of crude protein follow the same pattern shown for fat-free lean gain data.

Blood metabolites

The effects of dietary crude protein on plasma urea concentration are presented in Figure 1. The sex effect observed on day 0 indicates that at a body weight of 75 lb gilts selected for this experiment were more efficient in utilizing dietary protein than barrows fed the same diet. Protein concentration had linear and quadratic effects (P < 0.01) on plasma urea concentration during weeks 1 and 4 of the experiment and a linear effect during weeks 2 and 3. Barrows and gilts fed the 10 and 14% CP diets had similar plasma urea concentrations throughout the experiment. Although barrows fed the 18% CP diet had an intermediate concentration of plasma urea and a concentration that remained similar throughout the experiment, gilts fed the 18% CP diet had a low plasma urea concentration of d 0 and 7 which increased on day 14 and 21 and then decreased on day 26. This fluctuation in plasma urea concentration in gilts fed the 18% CP diet is similar to the change in ADFI of these gilts which was 3.57, 3.88, 3.90, and 3.55 lb/d for weeks 1 through 4, respectively. Pigs fed the 22% CP diet had the greatest plasma urea concentration throughout the experiment. The plasma urea data indicate that the CP requirement for gilts during the 4-week experimental period was > 18% CP which was

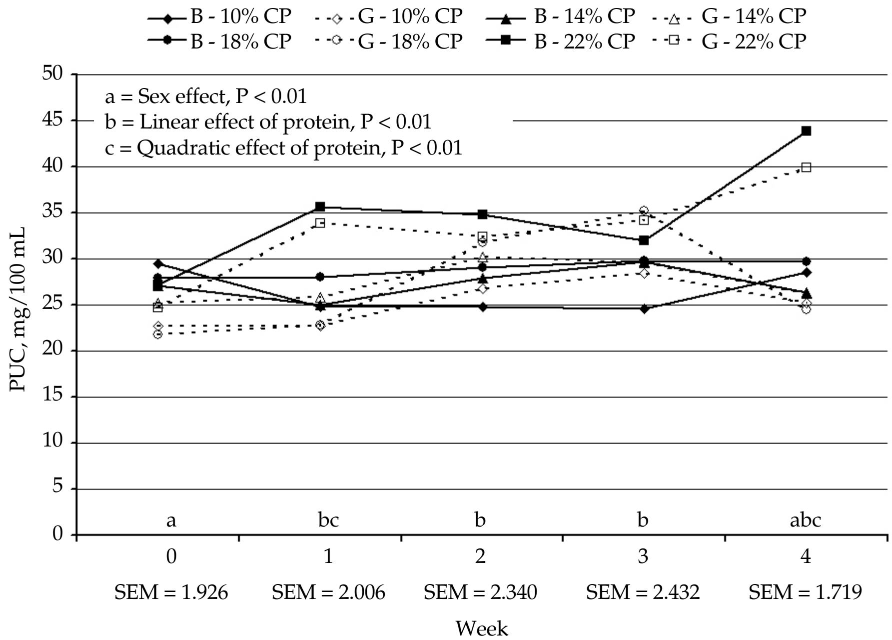

Figure 1. Response of plasma urea concentration (PUC) to experimental diets by week.

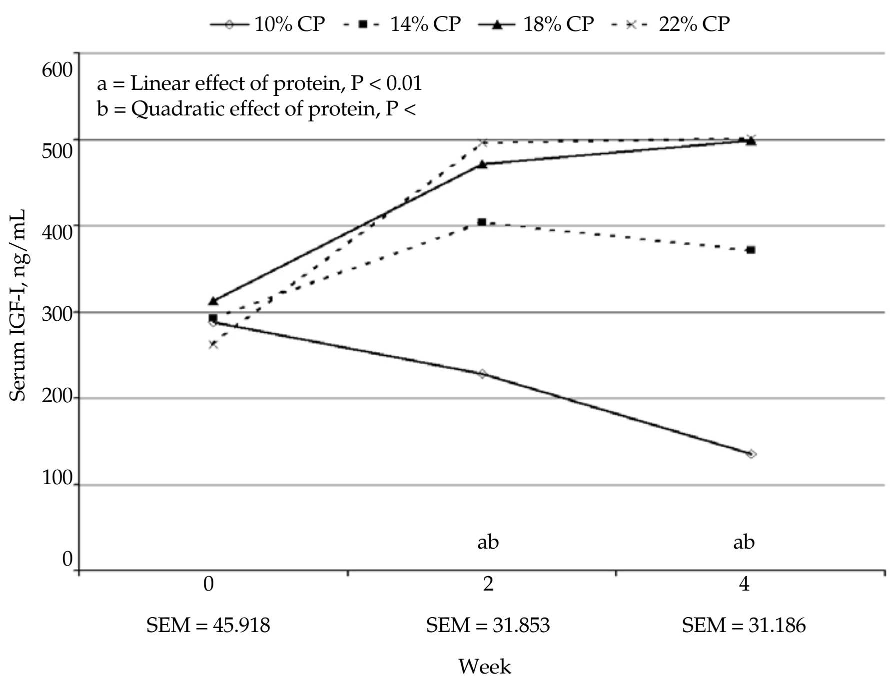

Figure 2. Response of serum insulin-like growth factor-I (IGF-I) to experimental diets by week.

also supported by the FFLG data.

Serum IGF-I concentrations are presented in Figure 2. Protein concentration had linear and quadratic effects ($P < 0.01$) on serum IGF-I concentration during weeks 2 and 4 of the experiment. There were no sex effects detected for serum IGF-I concentration, thus the data for barrows and gilts within dietary crude protein concentration were pooled and presented in Figure 2. Pigs fed the diet containing 10% CP had the lowest IGF-I concentration throughout the experiment and pigs fed the 18 and 22% CP had similar IGF-I concentration during weeks 2 and 4 of the experiment. These serum IGF-I concentrations indicate that the production and release of IGF-I into the blood is inhibited by the consumption of a 10 or 14% CP diet. This reduction in serum IGF-I is supported by the reduced fat-free lean accretion rates calculated for the pigs consuming the 10 and 14% crude protein diet. However, pigs fed the 18 and 22% CP diets had numerically similar serum IGF-I concentrations, and pigs fed the 18% CP diet had a significant decrease in FFLG as compared to pigs fed the 22% CP diets. These results suggest that the consumption of a diet marginally deficient in CP (18%) does not inhibit the production of IGF-I. However, the actions of IGF-I (i.e., muscle protein accretion) are partially inhibited. This diminished action of IGF-I is supported by the reduction in FFLG observed for pigs fed the 18% CP diet.

Conclusions

Results from this experiment demonstrate that growing pigs respond to increased dietary crude protein concentration, which is supported by the improvement in ADG, feed efficiency and fat-free lean gain in pigs fed up to 22% crude protein. A similar effect was detected in plasma urea concentration. Pigs fed the 22% CP diet had an increase concentration of plasma urea compared to the pigs fed the 10, 14, and 18% CP diet, indicating that the CP requirement of gilts in this experiment was > 18% CP. However, serum IGF-I concentrations were decreased in pigs fed the 10 and 14% CP diets, indicating that the consumption of a diet below the pigs dietary crude protein requirement (18%) was not always associated with a reduction in IGF-I serum concentration. Therefore, future research in this area will focus on the relationship between carcass protein accretion and serum IGF-I concentration. Also, the effect of crystalline amino acids will be investigated to determine their effects on serum IGF-I concentration and how the pattern of dietary crystalline amino acid supplementation can be manipulated in diets for growing-finishing pigs without creating negative effects on carcass protein accretion rates.

[1]Robert L. Fischer is a research technologist and graduate student and Phillip S. Miller is a professor in the Department of Animal Science.