January 2004

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

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Summary and Implications

This study was conducted to investigate the effects of increasing dietary protein intake on growth performance and serum insulin-like growth factor-I (IGF-I) concentration in growing-finishing gilts. Thirty-nine crossbred gilts with an initial body weight of 74.3 lb were used in a 28-day growth study. The gilts were randomly allocated to one of five dietary treatments. The diets were standard corn soybean meal diets, which were formulated to contain 10, 14, 18, 22, or 26% crude protein by changing the ratio of corn to soybean meal in the diet. Pig and feeder weights were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI) and 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 the treatments throughout the 28-day experimental period. Dietary protein concentration had significant linear and quadratic effects on ADG and ADG/ADFI (P < 0.01). Gilts fed the diet containing 22% CP had the greatest accretion rate of fat-free lean (0.82 lb/d); however, gilts fed the 18 and 26% CP diets had numerically similar fat-free lean accretion rates. Increased dietary protein concentration resulted in increased cold carcass weight (linear, P < 0.01; quadratic, P < 0.01) with no differences in carcass dressing percentage. Protein concentration had a significant quadratic effect (P < 0.01) on plasma urea and serum IGF-I concentration during weeks 1 thru 4 of the experiment. In summary, dietary protein concentration had significant linear and quadratic effects on final body weight, ADG, feed

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

	Dietary protein concentration, %				
Item	10	14	18	22	26
Ingredient, %					
Corn	89.10	79.00	69.10	59.00	49.00
Soybean meal, 46.5% CP	5.50	15.75	25.75	36.00	46.10
Tallow	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.05	1.00	0.95	0.85	0.80
Limestone	0.70	0.65	0.58	0.55	0.50
Salt	0.30	0.30	0.30	0.30	0.30
Vitamin premix[a]	0.20	0.20	0.20	0.20	0.20
Mineral premix[b]	0.15	0.15	0.15	0.15	0.15
Analyzed nutrient composition					
Dry matter, %	90.33	90.77	91.04	90.93	91.52
Crude protein, %	9.15	13.60	17.54	22.17	25.82
Lysine, %	0.37	0.64	0.87	1.17	1.37
Calcium, %	0.66	0.71	0.68	0.68	0.77
Total phosphorus, %	0.47	0.54	0.57	0.60	0.69
Crude fat, %	5.08	4.96	4.82	4.57	4.41

[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 $FeSO_4 \bullet H_2O$),128 mg; Mn (as MnO), 30 mg; Cu (as $CuSO_4 \bullet 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \bullet H_2O$), 0.26 mg; Se (as Na_2SeO_3), 0.3 mg.

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 in gilts fed the 14% CP diet was not associated with a decrease in serum IGF-I concentration. This finding suggests that something is inhibiting the actions of IGF-I protein by causing a decrease in protein accretion rate in these gilts. 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.

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 this potential 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 fill the gaps in our 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 the dietary concentration 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 (first step toward attaining our long-range goal) is to demonstrate *in vivo* the effect of increasing dietary protein intake on serum IGF-I concentration.

Procedures

Animals and Treatments

Thirty-nine crossbred [Danbred × (Danbred × NE White Line)] gilts were used in a 28-day growth study. Pigs averaged 74.3 and 126.3 lb at the initiation and termination of the experiment, respectively. Four gilts were randomly selected for an initial slaughter group for the collection of tissue samples. The remaining 35 gilts were randomly assigned to one of five dietary treatments. The diets (Table 1) were standard corn soybean meal diets, which were formulated to contain 10, 14, 18, 22, or 26% 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 the NRC (1998) requirements for 45-lb pigs. The pigs were housed in an environmentally controlled room 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 feed efficiency (ADG/ADFI). Fat-free lean gain (FFLG) was calculated from backfat (BF) thickness and longissimus muscle area (LMA); BF and LMA were obtained on the first and the last day of the experiment using real-time ultrasound using the National Pork Producers Council (1991) equation. Plasma urea and serum insulin-like growth

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

Item		Dietary protein concentration, %							
		10	14	18	22	26	SEM	Linear	Quadratic
Number of pigs		7	7	7	7	7			
Growth performance									
	Initial wt., lb	73.65	74.75	74.31	73.43	74.75	0.827	NS	NS
	Final wt., lb	106.07	127.67	131.42	133.62	132.30	2.624	< 0.01	< 0.01
d 0 to 28									
	ADG, lb [a]	1.15	1.87	2.03	2.14	2.05	0.073	< 0.01	< 0.01
	ADFI , lb [b]	4.06	4.41	4.01	4.17	3.95	0.141	NS	NS
	ADG/ADFI	0.28	0.42	0.51	0.52	0.52	0.010	< 0.01	< 0.01
	Lysine intake, g/d	6.82	12.77	15.81	22.12	24.51	0.647	< 0.01	NS
Ultrasound measurements									
Initial	Backfat, in	0.32	0.34	0.34	0.32	0.33	0.015	NS	NS
	LMA, in^2 [c]	2.44	2.39	2.36	2.43	2.45	0.064	NS	NS
Final	Backfat, in	0.47	0.51	0.44	0.38	0.41	0.017	< 0.01	NS
	LMA, in^2	3.01	3.82	4.01	3.92	4.04	0.123	< 0.01	< 0.01
	FFLG, lb/d [d e]	0.35	0.69	0.80	0.82	0.80	0.035	< 0.01	< 0.01
Carcass measurements									
	Cold carcass wt., lb	78.79	96.00	98.64	99.36	99.14	1.962	< 0.01	< 0.01
	Dressing, %	74.38	75.23	75.00	74.32	74.87	0.504	NS	NS

[a]ADG = average daily gain.
[b]ADFI = average daily feed intake.
[c]LMA = longissimus muscle area.
[d]FFLG = fat-free lean gain.
[e]Calculated from equation of NPPC, 1991.

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 effect in the statistical model was dietary protein concentration (10, 14, 18, 22, and 26% CP). 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.

Results and Discussion

Growth Performance

The response of ADG, ADFI and ADG/ADFI to dietary treatments are shown in Table 2. There was no difference (P > 0.10) in ADFI among the treatments throughout the 28-day experimental period. Protein concentration had significant linear and quadratic effects on ADG and feed efficiency (P < 0.01). Average daily gain increased as the dietary concentration of crude protein increased from 10% (1.15 lb/d) to 22% dietary CP (2.14 lb/d; a 54% improvement in gain) then slightly decreased in gilts fed the diet containing 26% CP (2.05 lb/d). Feed efficiency followed a similar pattern as ADG. Gilts fed the 10% dietary CP had the lowest ADG/ADFI (0.35) and those fed the diets containing 22% and 26% CP had the greatest ADG/ADFI (0.52; a 62% improvement in feed efficiency).

Carcass Characteristics

Real-time ultrasound measurements recorded on days 0 and 27 are summarized in Table 2. At the initiation of the experiment there were no differences (P > 0.10) in tenth-rib BF depth or LMA among the dietary treatments. However, at the end of the experiment, there was a significant linear effect of dietary protein (P < 0.01) on tenth-rib BF depth and linear and quadratic effects (P < 0.01) on LMA. Gilts fed the diet containing 22% CP had the lowest BF (0.38 in) and gilts fed the 14% CP diet had the greatest BF (0.51 in). The greater amount of BF detected in the gilts fed the diet containing 14% CP could be due to the numerically greater ADFI observed for these gilts. Longissimus muscle area was similar among the gilts fed the diets containing 14% through 26% CP (3.82, 4.01, 3.92, 4.04 in^2, respectively); however, gilts fed the 10% dietary CP had a reduction in LMA (3.01 in^2). Protein concentration had a significant quadratic effect on fat-free lean (P < 0.01). Gilts fed the diet containing the 22% CP had the greatest accretion rate of fat-free lean (0.82 lb/d). Gilts fed the 18 and 26% CP diets had numerically similar fat-free accretion rates (0.80 and 0.80 lb/d, respectively). The

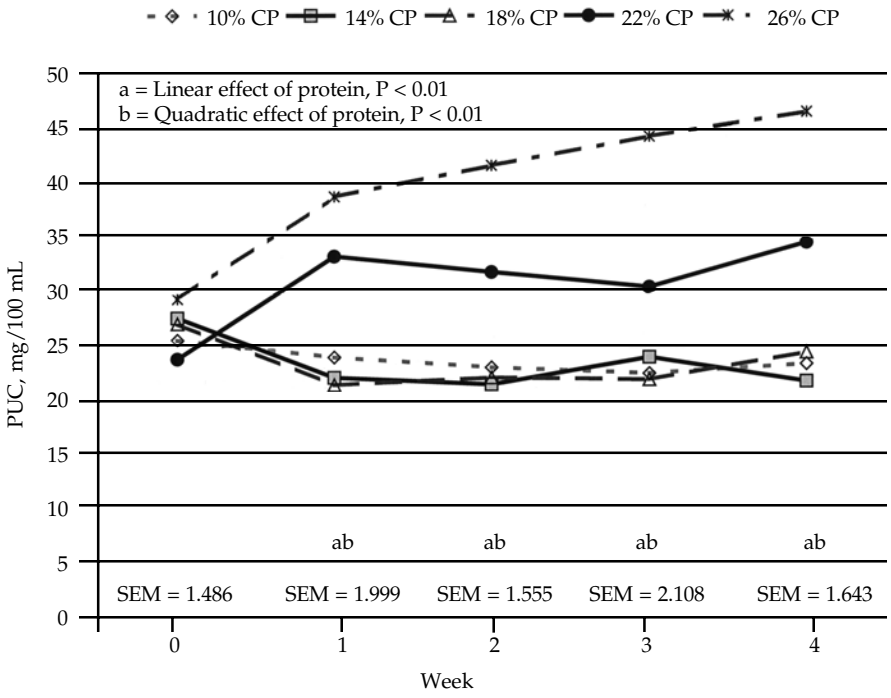

Figure 1. Response of plasma urea concentration (PUC) to experimental diets by week.

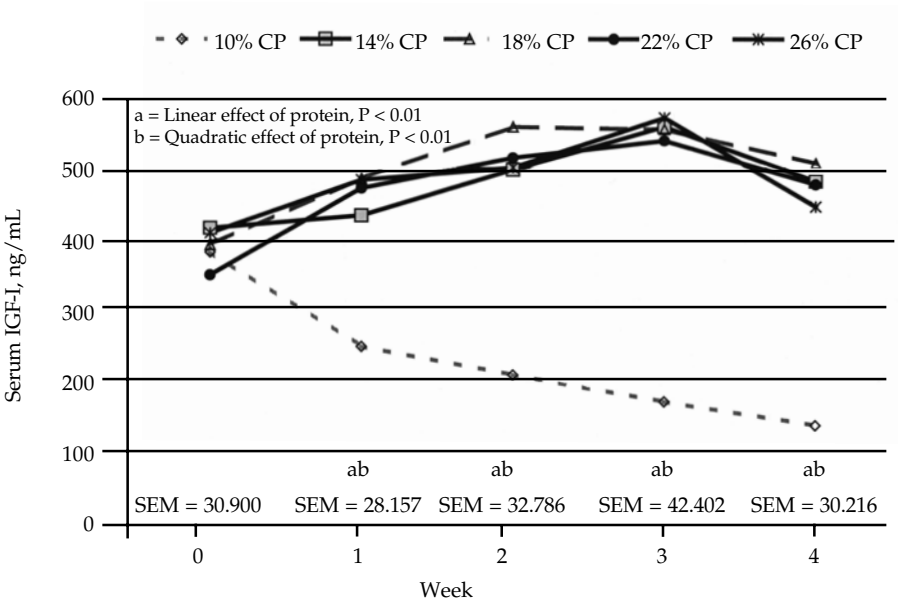

Figure 2. Response of serum insulin-like growth factor-I (IGF-I) to experimental diets by week.

NRC (1998) requirements for swine suggest a total lysine intake of 17.5 grams/day for pigs weighing 44 to 110 lb and accreting 0.72 lb/day of fat-free lean. Thus, gilts fed the diets containing 10 and 14% CP consumed approximately 7 and 13 grams of lysine/day, respectively, which was less than the amount suggest by the NRC (1998) to maximize fat-free lean accretion. Thus, the fat-free lean data suggest that the CP requirement for gilts in the present study was ≥ 18% from 74 to 126 lb of body weight. Increased dietary protein concentration resulted in increased cold carcass weight (quadratic, P < 0.01) with no differences in carcass dressing percentage.

Blood Metabolites

The effects of dietary crude protein on plasma urea concentration are illustrated in Figure 1. Protein concentration had significant linear and quadratic effects (P < 0.01) on plasma urea concentration during weeks 1 thru 4 of the experiment. Gilts fed the 10, 14 and 18% CP diets had similar plasma urea concentrations throughout the experiment. While gilts fed the 22% CP diet had an intermediate concentration of plasma urea, and gilts fed the 26% CP diet had the highest plasma urea concentration. The plasma urea data indicate that the CP requirement for gilts during the four-week experimental period was ≥ 18% CP which also was supported by the FFLG data.

Serum IGF-I concentrations are presented in Figure 2. Protein concentration had significant linear and quadratic effects (P < 0.01) on serum IGF-I concentration during weeks 1 thru 4 of the experiment. Gilts fed the diet containing 10% CP had the lowest IGF-I concentration throughout the experiment and gilts fed the 18% CP had the highest IGF-I concentration during the experiment, except during week 3. 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% CP diet. This reduction in serum IGF-I is supported by the low fat-free lean accretion rates calculated in the gilts consuming the 10% crude protein diet. However, gilts fed the 14, 18, 22 and 26% CP diets had numerically similar serum IGF-I concentrations. However, gilts fed the 14% CP diet had a significant decrease in FFLG as compared to gilts fed the 18, 22, and 26% CP diets. These results would suggest that the consumption of a diet slightly deficient in CP (14%) does not inhibit the pro-

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duction of IGF-I. However, the actions of IGF-I in the body (i.e., muscle protein accretion) are in some way inhibited (i.e., receptor binding, receptor concentration, IGF-I binding proteins) which is supported by the reduction in FFLG in gilts fed the 14% CP diet.

Conclusions

The results from this experiment demonstrate that growing gilts respond to increased dietary crude protein concentration, which is supported by the improvement in ADG, feed efficiency and fat-free lean gain in gilts fed up to 22% crude protein. A similar effect was detected in plasma urea concentration. Gilts fed the 22% CP diet had an increase concentration of plasma urea compared to the gilts fed the 10, 14 and 18% CP diet, indicating that the CP requirement of gilts in this experiment was $\geq$ 18% CP. However, serum IGF-I concentrations were only decreased in gilts fed the 10% CP diet, indicating that the consumption of a diet below the gilts dietary crude protein requirement (14%) was not always associated with a reduction in IGF-I serum concentration. Thus, 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 having a negative effect 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.