Effect of Dietary Crude Protein Versus Crystalline Amino Acids on Growth Performance, Serum Insulin-Like Growth Factor-I Concentration, and IGF-I mRNA Expression in Growing-Finishing Gilts

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Summary and Implications

Fifty-six crossbred gilts with an initial body weight of 73 lb were used in a 26-day growth study. The pigs were randomly allocated to one of seven dietary treatments and individually penned (8 replicates/treatment). The dietary treatments consisted of four standard corn-soybean meal diets, which were formulated by changing the corn and soybean meal (10, 14, 18, and 22% CP) ratio and three low-protein, amino acid-supplemented diets formulated to contain similar lysine, methionine, tryptophan, and threonine concentrations as the corn-soybean meal diets (10% CP + AA,14% CP + AA, and 18% CP + AA). Pig and feeder weights were recorded weekly for the determination of ADG, ADFI, and feed efficiency (ADG/ADFI). Blood samples were collected weekly and analyzed for plasma urea and Insulin-like Growth Factor –I (IGF-I) concentrations. On day 26, real-time ultrasound backfat and longissimus muscle area measurements were recorded and used for the calculation of fat-free lean gain. There was no difference (P > 0.10) in ADFI among treatments throughout the 26-day period. Pigs fed the corn-soybean meal diets (14, 18, and 22% CP) had greater ADG (1.81 versus 1.68 lb; P < 0.05) and ADG/ADFI (0.44 versus 0.40 lb/lb; P < 0.05) than pigs fed the reduced CP amino acid-supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA) throughout the experiment. Fat-free lean gain increased as dietary CP or total amino acid concentration increased (P< 0.01); however, no differences (P > 0.40) were observed between gilts fed the corn-soybean meal (378 g/day) versus CP amino acid-supplemented diets (368 g/day). Increasing dietary CP or total amino acid concentration increased serum IGF-I concentrations on day 26 (P < 0.01). Serum concentration was different (P < 0.05) between gilts fed the corn-soybean meal versus low-CP, amino acid-supplemented diets (505 vs. 445 ng/mL, respectively). Real-time PCR results indicated an effect (P < 0.05) of dietary treatment on mRNA expression in the liver and semitendinosus muscle. Also, IGF-I mRNA expression was greater (P < 0.01) in the semitendinosus muscle and adipose tissue of gilts fed corn-soybean meal diets compared to gilts fed low-protein, amino acid-supplemented diets. These results suggest that the form of dietary amino acid supplementation affects serum IGF-I concentrations and mRNA expression in semitendinosus muscle and adipose tissue. The interaction between diet and the pig's growth potential are complex. The form and quantity of dietary amino acids impact this interaction. These results provide a basis to explore how diet affects the metabolic signals (e.g., IGF-I) regulating growth in the pig.

Introduction

Excessive excretion of nitrogen by livestock operations is a major environmental concern. To reduce the excretion of nitrogen from swine operations, the use of crystalline amino acids (AA) has become an important part of diet formulation within the pork industry. Crystalline AA are relatively purified sources of AA that can be added to swine diets to meet the AA requirements of pigs. The use of crystalline AA allows producers to reduce feed cost per pound of pork sold, especially during times of high soybean meal prices, and also helps producers reduce nitrogen excretion to help prevent damage to the environment. A decrease in nitrogen excretion will decrease the number of acres required for manure application. It has been estimated that for each one percentage unit reduction in CP, a 10-acre reduction will result in the land requirement for manure application for a 1,000-pig finishing operation. In addition, odors from pig manure can be offensive particularly to people not associated with agriculture, and can be a major nuisance factor. Ammonia, hydrogen sulfide, and other volatile gases that originate from the decomposition of swine manure are decreased when pigs are fed low-protein, amino acid-supplemented diets. Research indicates that for each one percentage point decrease in dietary CP there is a

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

Item	Dietary protein concentration, %						
	10	14	10+AA	18	14+AA	22	18+AA
Ingredient, %							
Corn	89.10	79.00	89.10	69.10	78.95	59.00	69.10
Soybean meal, 46.5% CP	5.50	15.75	5.50	25.75	15.75	36.00	25.75
Tallow	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.05	1.00	1.05	0.95	1.00	0.85	0.95
Limestone	0.70	0.65	0.70	0.58	0.65	0.55	0.58
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix [a]	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Mineral premix [b]	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine•HCl	—	—	0.20	—	0.215	—	0.22
Threonine	—	—	0.036	—	0.036	—	0.045
Tryptophan	—	—	0.096	—	0.105	—	0.105
Methionine	—	—	0.033	—	0.033	—	0.039
Composition, %							
CP [c]	10.05	13.92	10.37	18.11	14.55	22.01	18.30
Lysine [d]	0.39	0.65	0.65	0.92	0.92	1.19	1.19
Calcium [d]	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Total phosphorus [d]	0.23	0.23	0.23	0.23	0.23	0.23	0.23
ME, Mcal/lb [d, e]	1.58	1.57	1.56	1.57	1.57	1.57	1.56

[a]Supplied per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 440 IU; α-tocopheryl 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.
[c]Analyzed value.
[d]Calculated value.
[e]Metabolizable energy.

10 to 12.5% reduction in ammonia emissions.

The reduction of nitrogen excretion by pigs fed a crystalline amino acid supplemented-diet is a positive effect of feeding crystalline AA. There are however, negative effects of the reduction in CP and addition of crystalline amino acids on the rate and composition of growth in growing-finishing pigs. Many research groups have reported similar performance between pigs fed corn-soybean meal and amino acid-supplemented diets; whereas, other researchers have reported a reduction in growth performance in pigs fed amino acid- supplemented diets. A reduction in muscle protein accretion rate and an increase in fat deposition in pigs fed AA supplemented diets have been observed in some studies, whereas in other experiments no differences were detected in protein and fat accretion between corn-soybean meal and AA supplemented diets.

To date, no research has been conducted to investigate the effect of crystalline amino acids on gene expression of Insulin-like Growth Factor-I (IGF-I) and concentrations of serum IGF-I in growing-finishing pigs. The research described seeks to fill the gaps in our current knowledge of how the use of crystalline AA affects protein accretion by gaining a greater understanding of how IGF-I is affected by the dietary concentration of CP and(or) amino acids in swine growing-finishing diets. Therefore, the objective of this experiment was to investigate in vivo, the effect of increasing dietary protein and(or) crystalline AA on serum IGF-I concentration and tissue IGF-I mRNA expression in growing gilts.

Materials and Methods

Animals and Treatments

Sixty crossbred [Danbred (Danbred Nebraska White Line)] gilts were used in a 26-day growth study. Pigs averaged 73.0 ± 1.94 and 115.8 ± 1.36 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 56 gilts were randomly assigned to one of seven dietary treatments. The diets (Table 1) were standard corn-soybean meal diets or low-protein, amino acid-supplemented diets. The corn-soybean meal diets were formulated by changing the corn and soybean meal ratio and the three low-protein, amino acid-supplemented diets were formulated by reducing the CP concentration by four percentage units with the removal of soybean meal and adding back crystalline AA so that the amino acid-supplemented diets contained similar lysine, methionine, tryptophan, and threonine concentrations as the corn-soybean meal diets. The dietary treatments were 1) 10% CP diet; 2) 14% CP diet; 3) 10% CP + AA; 4) 18% CP; 5) 14% CP + AA; 6) 22% CP; and 7) 18% CP + AA. Diets were fortified with vitamins and minerals to meet or exceed

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the NRC (1998) requirements for 100-lb pigs. Pigs were housed individually and allowed ad libitum access to feed and water throughout the experiment. All experimental protocols were approved by the University of Nebraska Institutional Animal Care and Use Committee.

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), Backfat and LMA were obtained on the first and the last day of the experiment using real-time ultrasound and fat-free lean was calculated using the National Pork Producers Council (2000) equation. Plasma and serum samples were collected weekly.

The gilts were slaughtered and organs were separated and weighed immediately after slaughter. Weights of the following organs were obtained: 1) heart with blood clots removed; 2) liver with gall bladder removed; 3) kidneys; 4) pancreas with associated fat tissue removed; 5) lungs with trachea removed; 6) stomach, which was weighed full and after contents were removed; and 7) gastrointestinal tract, which was weighed full and after contents were removed. Gastrointestinal tract was separated into small and large intestines and mesentery. Contents of the stomach and gastrointestinal tract were removed for the determination of empty body weight (live weight minus gastrointestinal content weight). Hot carcass weight was measured and the carcasses were subsequently chilled at 4°C for 24 hours. After chilling, cold carcass weight; LMA at the tenth-rib; carcass length; tenth-rib backfat 3/4 distance along the longissimus muscle of the ribbed carcass; and midline BF depths at first-rib, 10th-rib, last-rib, and last-lumbar vertebrae were measured on each carcass. Carcasses were ground and sub samples were placed in plastic bags and frozen.

Tissue Sampling

Within 20 to 30 minutes of slaughter, tissue samples for real-time PCR were collected from different locations on the carcass. The samples collected included a liver sample from the upper left medial lobe, longissimus muscle taken at the 10th rib, semitendinosus muscle, and an abdominal subcutaneous adipose tissue sample.

Sample Analysis

Diet samples were analyzed in duplicate for DM, CP, Ca, and P. Plasma samples were analyzed for urea concentration. The concentration of IGF-I in serum was determined using a commercially available two-site immunoradiometric assay. This assay measured total serum IGF-I.

Total RNA was extracted from tissue samples using TRI-Reagent. Samples were treated with 5 units of RQ1 RNase-free DNase to remove residual genomic DNA. The 5 μg sample of total RNA was reverse transcribed into cDNA using SuperScript III reverse transcriptase.

The quantification of target cDNA coding for IGF-I and GapDH in liver, longissimus muscle, semitendinosus muscle, and adipose tissue was performed by real-time RT-PCR. The GapDH gene was chosen as a housekeeping gene and the relative concentrations of IGF-I mRNA results are expressed as the ratio IGF-I/GapDH.

Statistical Analysis

Data were analyzed as a completely randomized design using PROC MIXED of SAS. The main effect in the statistical model was dietary protein treatment and the comparison between source of amino acids, which was the comparison of corn-soybean meal diets (14, 18, and 22% CP) versus low-protein, amino acid-supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA.). For plasma urea and serum IGF-I concentrations the data were analyzed within week to compare the effects of dietary CP and(or) AA concentration for each week of the experiment. In all analyses, pig was the experimental unit.

Results

Growth performance. There was no difference ($P > 0.10$) in ADFI among the seven dietary treatments or between the corn-soybean meal versus the amino-acid supplemented diets throughout the 26-day experimental period (Table 2). Increasing protein concentration and amino acid concentration increased ADG, final weight, and feed efficiency ($P < 0.01$). Average daily gain increased as the dietary concentration of crude protein and(or) amino-acid supplementation increased, from 1.04 lb in gilts fed the 10% CP diet to 1.96 lb in gilts fed the 22% CP and 18% CP+AA diets ($P < 0.01$). Feed efficiency followed a similar pattern as ADG. Gilts fed the 10% dietary CP had the lowest ADG/ADFI (0.26 lb/lb) and gilts fed the diets containing 22% CP and 18% CP + AA had the greatest ADG/ADFI (0.47 lb/lb; a 55% improvement in feed efficiency; $P < 0.01$). There was a difference ($P < 0.05$) in ADG and ADG/ADFI between gilts fed the corn-soybean meal diets versus the low-protein, amino acid-supplemented diets with gilts fed the corn-soybean meal diets having greater ADG and ADG/ADFI than the gilts fed the amino acid-supplemented diets mainly due to the decrease in growth performance in gilts fed the 10% CP + AA diet.

Table 2. Effect of protein concentration and crystalline amino acids on growth performance of growing gilts.

		Dietary treatment								Main Effects [a]	
Item		10	14	10+AA	18	14+AA	22	18+AA	SEM	TRT	CP vs AA
Total number of pigs		8	8	8	8	8	8	8			
Growth performance											
	Initial wt, lb	73.18	72.54	73.18	73.05	73.43	72.76	72.85	1.940	NS	NS
	Final wt, lb	99.97	113.51	104.91	122.11	122.00	123.88	123.88	2.992	< 0.01	NS
d 0 to 26	ADG, lb [b]	1.04	1.56	1.21	1.90	1.87	1.96	1.96	0.104	< 0.01	< 0.05
	ADFI, lb [c]	3.86	4.08	3.64	4.26	4.30	4.17	4.17	0.181	NS	NS
	ADG/ADFI, lb/lb	0.26	0.39	0.33	0.45	0.44	0.47	0.47	0.012	< 0.01	< 0.05
Ultrasound measurements											
Initial	Backfat, in	0.32	0.31	0.30	0.31	0.31	0.31	0.31	0.016	NS	NS
	LMA [d], in^2	2.14	2.05	2.20	2.12	2.09	2.12	2.19	0.087	NS	NS
Final	Backfat, in	0.42	0.43	0.37	0.39	0.42	0.40	0.39	0.022	NS	NS
	LMA, in	2.62	3.16	3.45	3.72	3.52	3.70	3.79	0.128	< 0.01	NS
	FFLG [e f], g/day	183	307	301	412	379	417	425	16.8	< 0.01	NS

[a]Trt = comparison of seven dietary treatments, CP vs AA = comparison corn-soybean meal diets (14, 18, and 22% CP) versus low-protein, amino acid supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA), and NS = nonsignificant effect, P > 0.10.
[b]ADG = average daily gain.
[c]ADFI = average daily feed intake.
[d]LMA = longissimus muscle area.
[e]FFLG = fat-free lean gain
[f]Fat-free lean gain was calculated using equations from "Pork Composition and Quality Assessment Procedures" published by NPPC, 2000.

Carcass characteristics. At the initiation of the experiment, there were no differences (P > 0.10) in 10th-rib BF depth or LMA among the dietary treatments (Table 2). However, at the end of the experiment, there was an effect (P < 0.01) of dietary treatment on ultrasound LMA with no differences among the dietary treatments for ultrasound BF depth. Gilts fed the diets containing 18% CP, 14% CP + AA, 22% CP, and 18% CP + AA (3.72, 3.52, 3.70, 3.79 in^2, respectively) had similar LMA; however, gilts fed the 10% CP, 14% CP, and 10% CP + AA had a smaller LMA (2.62, 3.16, and 3.45 in^2, respectively). Protein and amino acid concentration had an effect (P < 0.01) on fat-free lean gain which increased as CP or total amino acid concentration increased in the diets. Gilts fed the diet containing the 18% CP + AA had the greatest accretion rate of fat-free lean (425 g/day) and gilts fed the 10% CP diet had the lowest FFLG (183 g/day) and there was no difference in FFLG in gilts fed either the corn-soybean meal (379 g/day) or the amino-acid supplemented diets (368 g/day).

Increased dietary protein concentration and total AA concentration resulted in increased hot carcass weights (P < 0.01); however, there was no difference between gilts fed corn-soybean meal versus amino acid-supplemented diets (83.46 and 83.17 lb, respectively, Table 3). Midline BF measurements and 10th-rib BF depth on ribbed carcasses were similar among the dietary treatments and no difference between corn-soybean meal versus amino acid-supplemented diets (0.30 and 0.36 in, respectively). Carcass LMA measured on the ribbed carcass at the 10th-rib increased (2.78, 3.62, 3.94, 4.24, 4.07, 4.42, and 4.26 in^2 , respectively; P < 0.01) as CP and(or) total AA concentrations increased with no difference between gilts fed corn-soybean versus amino acid- supplemented diets (4.09 versus 4.09 in^2 , respectively). Carcass length (24.54, 25.78, 24.66, 25.76, 25.66, 25.86, and 26.67 in, respectively; P < 0.05) increased as the concentration of CP and(or) total AA concentration in the diet increased and gilts fed the corn-soybean meal diets had longer carcass compared to gilts fed the low-protein, amino acid-supplemented diets (25.80 versus 25.27 in, P < 0.05). There was a trend (P < 0.10) for dressing percentage to increase as dietary CP and(or) total AA concentration increased and gilts fed the amino-acid supplemented diets (70.40%) had greater (P < 0.05) carcass dressing percentage compared to gilts fed the corn-soybean meal diets (68.71%).

Organ weights. Dietary CP and(or) total AA concentration resulted in an increase (P < 0.01) in empty body weight and there was no difference between gilts fed the corn-soybean meal versus AA supplemented diets (116.05 versus 113.97 lb; Table 4). Increased CP and(or) total AA concentration affected (P < 0.01) liver weight (1,054, 983, 895, 971, 941, 1,050, and 930 g, respectively) and gilts fed the corn-soybean meal diets had greater (P < 0.01) liver weights compared to gilts fed the AA-supplemented diets (1,001 and 922 g, respectively). Similar results were observed for kidney weight (186, 188, 167, 210, 192, 230, and 208

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Table 3. Effect of protein concentration and crystalline amino acids on carcass measuremnts of growing gilts.

	Dietary treatment								Main Effects[a]	
Item	10	14	10+AA	18	14+AA	22	18+AA	SEM	TRT	CP vs AA
Total number of pigs	8	8	8	8	8	8	8			
Carcass measurements										
Hot carcass wt, lb	67.80	77.24	74.31	86.19	86.02	86.94	89.19	2.622	< 0.01	NS
Midline backfat										
First-rib, in	1.12	1.09	1.04	1.06	1.08	1.06	1.05	0.046	NS	NS
Tenth-rib, in	0.54	0.49	0.55	0.52	0.56	0.57	0.56	0.036	NS	NS
Last-rib, in	0.50	0.47	0.47	0.46	0.49	0.52	0.48	0.035	NS	NS
Last lumbar, in	0.44	0.43	0.44	0.46	0.45	0.48	0.44	0.029	NS	NS
Other carcass measurements										
Tenth-rib, in	0.38	0.34	0.28	0.31	0.34	0.27	0.31	0.036	NS	NS
LMA[b], in^2	2.78	3.62	3.94	4.24	4.07	4.42	4.26	0.147	< 0.01	NS
Carcass length, in	24.54	25.78	24.66	25.76	25.66	25.86	26.67	0.281	< 0.05	< 0.05
Dressing %	67.80	67.27	70.00	69.50	70.49	69.36	70.71	0.943	< 0.10	< 0.05

[a]Trt = comparison of seven dietary treatments, CP vs AA = comparison corn-soybean meal diets (14, 18, and 22% CP) versus low-protein, amino acid supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA), and NS = nonsignificant effect, P > 0.10.
[b]LMA = longissimus muscle area.

Table 4. Effect of protein concentration and crystalline amino acids on organ weights of growing gilts.

	Dietary treatment								Main Effects [a]	
Item	10	14	10+AA	18	14+AA	22	18+AA	SEM	TRT	CP vs AA
Total number of pigs	8	8	8	8	8	8	8			
Empty body weight, lb	94.51	109.15	100.99	118.65	119.36	120.33	121.25	2.710	< 0.01	NS
Organ weights										
Heart, g	219	219	212	216	216	205	199	6.14 – 8.3	NS	NS
Liver, g	1,054	983	895	971	941	1,050	930	29.2 – 39.2	< 0.01	< 0.01
Kidney, g	186	188	167	210	192	230	208	6.3 – 8.5	< 0.01	< 0.01
Lungs, g	527	574	510	526	534	568	511	31.1 – 41.9	NS	NS
Pancreas, g	78	80	78	87	87	86	89	5.3 – 7.1	NS	NS
Stomach, g	369	367	365	327	353	342	320	9.1 – 12.3	< 0.02	NS
Small intestine, g	1,089	1,136	1,012	988	1,137	1,199	1,064	70.4 – 94.8	NS	NS
Large intestine, g	906	846	808	750	697	779	705	30.2 – 40.7	< 0.01	< 0.05
Mesentary, g	877	780	807	703	670	636	601	36.4 – 48.9	< 0.02	NS

[a]rt = comparison of seven dietary treatments, CP vs AA = comparison corn-soybean meal diets (14, 18, and 22% CP) versus low-protein, amino acid supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA), and NS = nonsignificant effect, P > 0.10.

Table 5. Effect of protein concentration and crystalline amino acids on carcass accretion of growing gilts.

	Dietary treatment								Main Effects [a]	
Item	10	14	10+AA	18	14+AA	22	18+AA	SEM	TRT	CP vs AA
Total number of pigs	8	8	8	8	8	8	8			
Cold carcass weight, lb	66.64	76.18	72.50	84.87	85.55	85.44	87.87	2.434	< 0.01	NS
Accretion rates, g/day										
Protein	40	67	70	117	116	119	128	5.7	< 0.01	NS
Water	106	212	199	339	333	353	369	20.7	< 0.01	NS
Fat	175	133	149	164	182	149	169	17.6	NS	NS
Ash	10	15	13	18	18	17	16	1.1	< 0.01	NS

[a]Trt = comparison of seven dietary treatments, CP vs AA = comparison corn-soybean meal diets (14, 18, and 22% CP) versus low-protein, amino acid supplemented diets (10% CP + AA, 14% CP + AA, and 18% CP + AA), and NS = nonsignificant effect, P > 0.10.

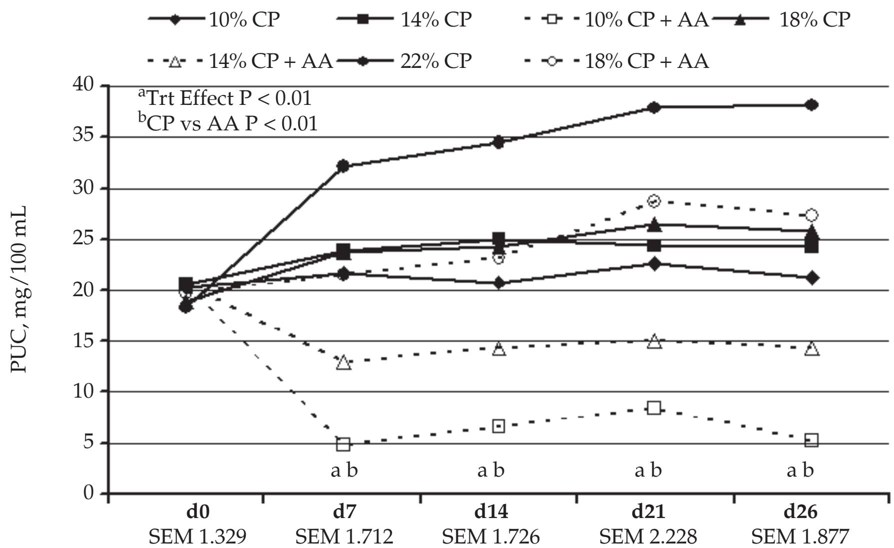

Figure 1. Response of plasma urea concentration (PUC) to experimental diets by week.

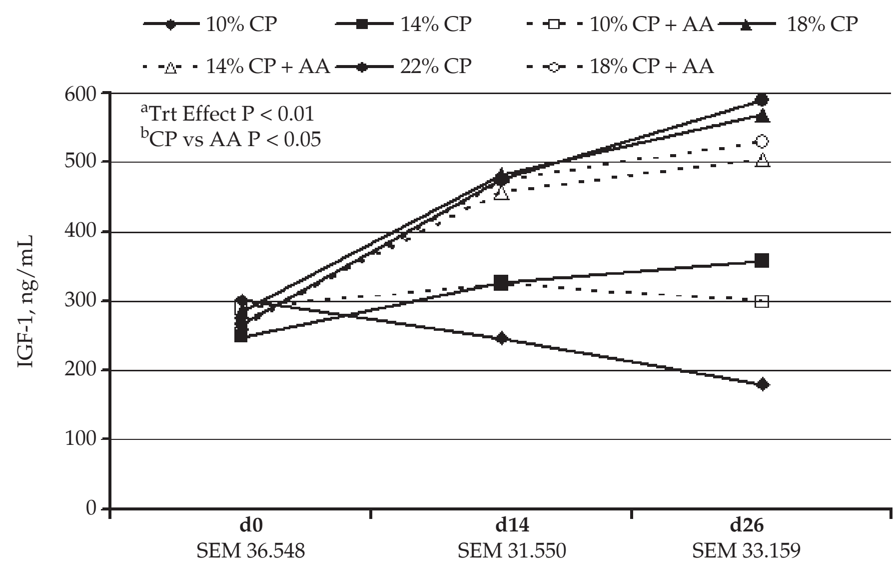

Figure 2. Response of serum insulin-like growth factor-I (IGF-I) to experimental diets by week.

g, respectively) with CP and(or) total AA concentration affecting (P < 0.01) kidney weights and gilts fed the AA-supplemented diets had lighter (P < 0.01) kidneys compared to gilts fed the corn-soybean meal diets (189 and 209 g, respectively). Stomach weight was affected (P < 0.02) by dietary treatment; however, there was no difference between gilts fed the corn-soybean versus AA-supplemented diets (345 and 346 g, respectively). Dietary treatment affected (P < 0.01) large intestinal weight and gilts fed the corn-soybean meal diets had greater (P < 0.05) large intestinal weights compared to gilts fed the AA-supplemented diets (792 and 737 g, respectively). There were no differences (P > 0.10) in the other internal organ weights (i.e., heart, lungs, spleen, small intestine, and mesentery) among dietary treatments and between corn-soybean meal versus AA-supplemented diets (Table 4).

Carcass accretion rate. Cold carcass weight increased (P < 0.01) as the concentration of dietary protein and(or) AA-supplementation concentration increased and gilts fed the corn-soybean meal and low-protein, amino acid-supplemented diets had similar (P > 0.10) cold carcass weights (82.16 and 81.98 lb, respectively, Table 5). Protein accretion rates increased (P < 0.01) from 40 g/d in gilts fed the 10% CP diet to 128 g/day in gilts fed the 18% CP + AA diet and there was no difference between gilts fed the corn-soybean meal versus the AA-supplemented diets (101 and 105 g/day, respectively). Dietary treatment increased (P < 0.01) carcass water accretion rate from 106 g/day in gilts fed the 10% CP diet to 369 g/day in gilts fed the 18% CP + AA diet and there was no difference (P < 0.10) between gilts fed the corn-soybean meal versus the AA-supplemented diets (301 and 300 g/day, respectively). Ash accretion rates increased (P < 0.01) as CP and(or) total amino acid concentration increased and there was a no difference between corn-soybean meal and AA-supplemented diets.

Blood metabolites. There was no difference among the seven dietary treatments on day 0 of the experiment; however, protein concentration and(or) AA supplementation had an effect (P < 0.01) on plasma urea concentration during week 1 thru 4 of the experiment (Figure 1). Gilts fed the amino acid-supplemented diets exhibited a decrease (P < 0.01) in plasma urea concentration compared to gilts fed the corn-soybean meal diets during week 1 through 4 of the experiment.

On day 0 there were no differences in serum IGF-I concentration among the seven dietary treatments; however, the increase in protein concentration and(or) AA supplementation resulted in an increase (P < 0.01) in serum IGF-I concentration during week 2 and 4 of the experiment (Figure 2). Gilts fed the corn-soybean meal diets had greater (505 ng/mL; P < 0.05)

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serum IGF-I concentrations compared to gilts fed the amino acid-supplemented diets (445 ng/mL) on day 26 of the experiment.

Tissue expression of mRNA. Liver IGF-I mRNA expression was affected by dietary treatment with gilts consuming the 18% CP diet having the greatest expression of IGF-I mRNA (Figure 3). Dietary CP concentration did not affect the expression of IGF-I mRNA in longissimus tissue (P = 0.20, Figure 4); however, there was an effect (P < 0.05) of dietary treatment on semitendinosus muscle. Gilts fed the corn-soybean meal diets had greater (P< 0.01) IGF-I mRNA expression in the semitendinosus muscle compared to the gilts fed the amino acid-supplemented diets (Figure 5). Insulin-like growth factor-I mRNA expression in adipose tissue was not different among the seven dietary treatments; however, gilts fed the corn-soybean meal diets had greater (P < 0.05) IGF-I mRNA expression compared to gilts fed the low- protein, amino acid-supplemented diets (Figure 6).

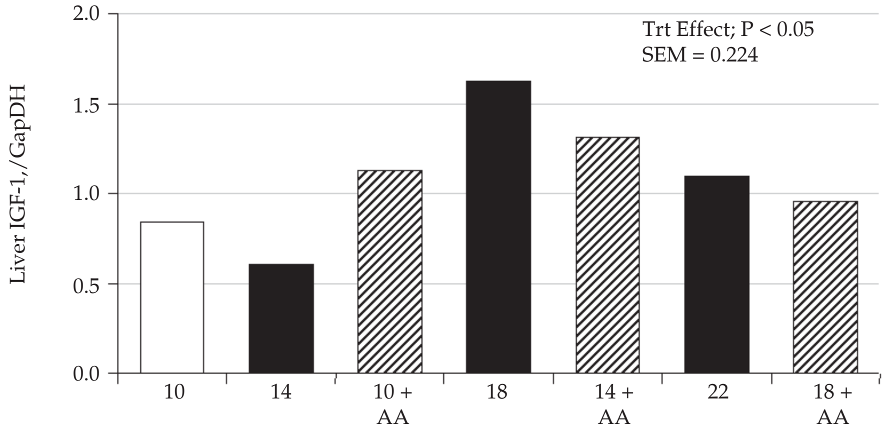

Figure 3. Effect of dietary treatment on liver IGF-I mRNA expression.

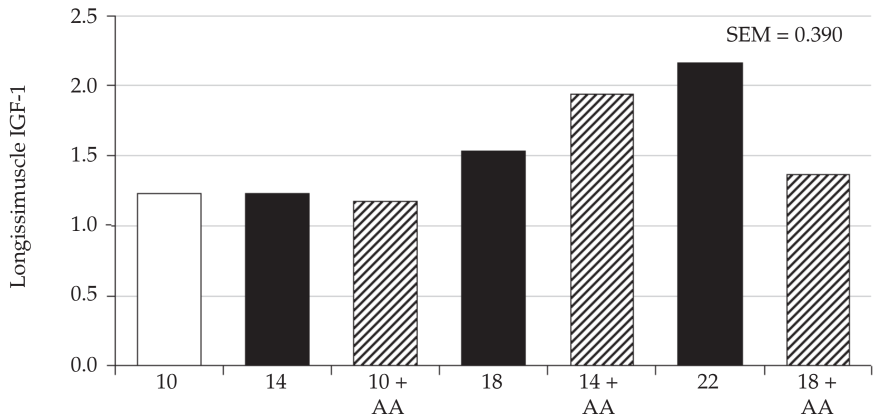

Figure 4. Effect of dietary treatment on longissimus muscle IGF-I mRNA expression.

Discussion

Previous studies investigating the effects of feeding pigs low-protein, amino acid-supplemented diets have reported a reduction in growth rate, decrease in carcass protein accretion, and increase in carcass fat accretion which could be due to a reduction in serum concentration and expression of IGF-I in various metabolic tissues. Results from this experiment do not support previous research (growth and carcass composition) because our results showed similar growth performance and carcass accretion rates in gilts fed corn-soybean meal diets compared to low-protein, amino acid-supplemented diets. However, gilts fed the corn-soybean meal diets did have greater serum IGF-I concentration and IGF-I mRNA expression in the semitendinosus muscle and adipose tissue compared to gilts fed the low-protein, amino acid supplemented diets.

Growth performance. Previous research conducted by our group showed an increase in body weight and ADG as the dietary CP concentration increased. In the current experiment, the increase in dietary CP and(or) total AA concentration resulted in an increase in ADG. Gilts fed the corn-soybean meal diets had greater ADG compared to the AA-supplemented diets. The reduced growth rate in gilts fed the 10% CP + AA diet is the main reason for the difference in ADG between gilts fed the corn-soybean meal versus AA-supplemented diets. Gilts fed the 10% CP + AA diet had similar feed intake compared to gilts fed the other diets. However, this diet was formulated to contain total amino acid concentrations below the gilts' requirements. The ratio of lysine to isoluceine and valine was lower than in the 14% CP diet and these lower AA ratios possibly caused the reduction in ADG. Gilts fed the 18% CP and 14% CP + AA diets and the 22% CP and 18% CP + AA had similar growth performance throughout the experiment. Feed intake was not different among the seven dietary treatments. Feed efficiency (ADG/ADFI) increased as a result of the increase in the dietary

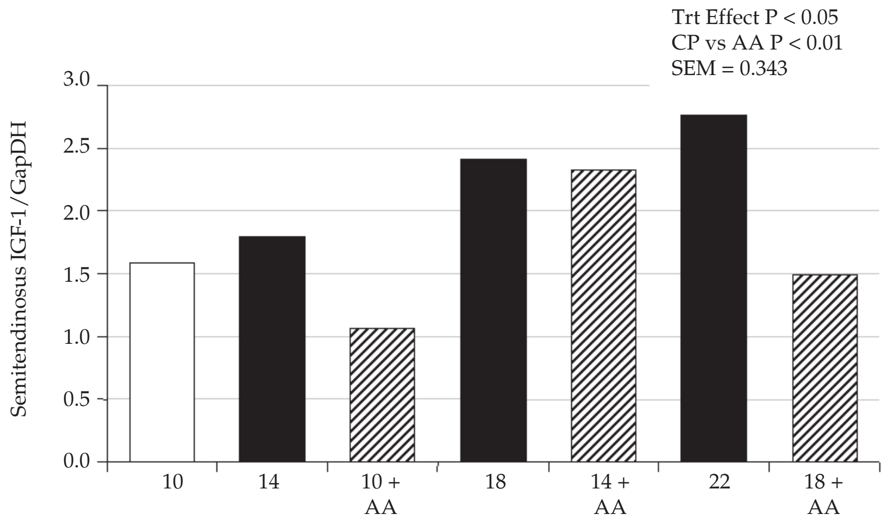

Figure 5. Effect of dietary treatment on semitendinosus muscle IGF-I mRNA expression.

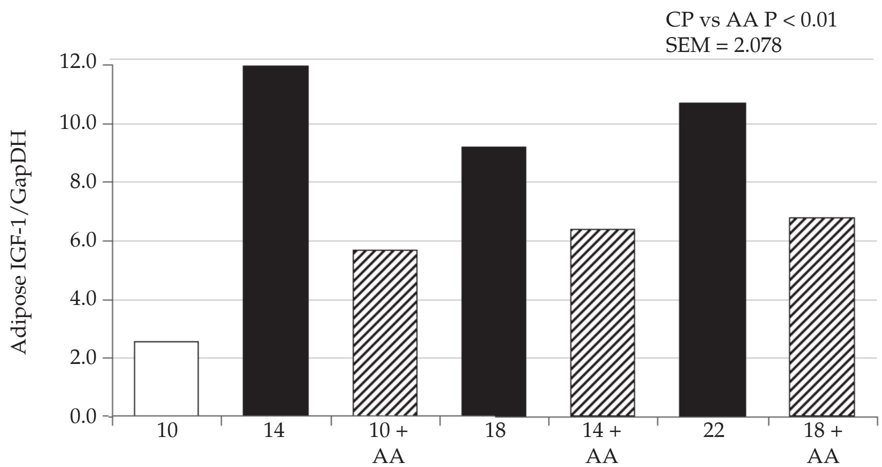

Figure 6. Effect of dietary treatment on subcutaneous adipose tissue IGF-I mRNA expression.

concentration of CP and(or) total AA. These results are similar to those from previous experiments; however, in this experiment, gilts fed the AA-supplemented diets exhibited a reduction in feed efficiency as compared to those fed the corn-soybean meal diets. The difference in feed efficiency between corn-soybean meal and AA-supplemented diets can again be attributed to the reduction in ADG observed in gilts fed the 10% + AA diet. Gilts fed the 18% CP, 14% CP + AA, 22% CP, and 18% CP + AA had numerically similar estimates for feed efficiency (0.45, 0.44, 0.47, and 0.47 lb/lb, respectively).

Carcass measurements. Ultrasound measurements taken on d 0 and 26 of the experiment showed no difference in BF depth among the seven dietary treatments or between gilts fed corn-soybean meal versus AA-supplemented diets. Also, carcass measurements taken 24-h after slaughter indicated no difference in 10th-rib BF depth among the dietary treatments or between corn-soybean meal and amino acid-supplemented diets. Carcass LMA increased as dietary CP and(or) AA concentration increased, but no differences were detected between corn-soybean meal and AA-supplemented diets. Using the National Pork Producers Council equations, FFLG increased as dietary CP and(or) dietary AA concentration increased from 183 g/day in gilts fed the 10% CP diet to 425 g/day in gilts fed the 18% CP + AA. Again, there was no difference between corn-soybean meal and AA-supplemented diets. The increase in LMA is not surprising because as the dietary CP intake increased from below the requirement, the concentration of AA available for muscle protein accretion increased.

Organ weights and carcass accretion rates. Empty body weight increased as CP and(or) AA concentration increased and there was no difference between gilts fed the corn-soybean meal and AA-supplemented diets. The reduction in dietary protein concentration in the AA-supplemented diets caused a reduction in liver and kidney weight because of the decrease in amino acids that must be processed by the liver and cleared from the body via the kidneys in the form of urea nitrogen. The decrease in stomach weight as dietary protein and(or) AA concentration increased is interesting in that there was no difference in ADFI. Cold carcass weight was increased as CP and(or) AA intake increased from below the requirements and no difference was observed in cold carcass weight between gilts fed the corn-soybean meal or AA-supplemented diets. The heavier cold carcass weight in pigs consuming a diet with a greater percentage of CP and(or) AA is supported by the increase in ADG.

Blood metabolites. Plasma urea concentrations were reduced when gilts were fed the low-protein, AA-supplemented diets compared to corn-soybean meal diets. An increase in plasma urea concentration is a metabolic response to the increase in protein intake once amino acid requirements are met or amino acid imbalances are created. As dietary protein intake

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increases above the requirement for protein accretion, the excess amino acids must be processed in the liver by deaminating the excess amino acids and removing the nitrogen by producing urea which is filtered out of the blood by the kidneys and excreted from the body in urine. Thus, feeding low-protein, AA-supplemented diets reduces the excess non-essential AA that are not used for protein deposition, and thus the nitrogen (urea) excreted is reduced. The increase in plasma urea concentration in the pigs fed the 22% CP diet indicates that the dietary CP requirement for pigs in this experiment was greater than 18% CP and is supported by the NRC (1998) model which suggests that the dietary CP requirement for high-lean gain gilts with a body weight of approximately 100 lb is 19.2% CP.

Gilts fed the 10% + AA and 14% CP had similar serum IGF-I concentrations and had IGF-I concentrations greater than gilts fed the 10% CP diet which had the lowest serum IGF-I concentration. The IGF-I concentrations increased from day 0 to day 14, and to day 26 of the experiment indicating that serum IGF-I concentration responded quickly to a change in dietary CP concentration. However, it was interesting to detect a difference in serum IGF-I concentration between the sources of amino acids, with gilts fed the corn-soybean meal diets having greater serum IGF-I concentrations as compared to the gilts fed the low-protein, AA-supplemented diet. Results from this experiment indicate that the production and release of IGF-I into the blood is inhibited by the consumption of a diet providing AA concentrations below the requirements (10% CP, 10% CP + AA, and 14% CP diets). This reduction in serum IGF-I is a possible causative factor in the reduction in FFLG and carcass protein accretion rates in the gilts consuming the 10% CP, 10% CP + AA, and 14% CP diets. These results suggest that the consumption of a diet deficient in CP and(or) amino acids does inhibit the production of IGF-I and the actions of IGF-I (i.e., muscle protein accretion) are partially inhibited.

Tissue IGF-I Expression. Expression of IGF-I mRNA in the longissimus muscle was not affected by dietary protein and(or) amino acid concentration. However, there was a significant increase in IGF-I mRNA in liver and semitendinosus muscle tissue. The data from the current experiment suggest that the circulating concentration of IGF-I does have an effect on muscle growth and that the actions of IGF-I on muscle may function in both an endocrine and autocrine/paracrine manner. This statement is supported by data from the current experiment that showed both a decrease in serum IGF-I concentration and reduced tissue mRNA expression in gilts fed diets not meeting amino acid requirements.

Conclusion

Results from this experiment demonstrate that growing gilts respond to increased dietary CP and(or) amino acid concentrations. As dietary CP and amino acid concentrations were increased in the diet from deficient to adequate concentrations there was an improvement in ADG, feed efficiency, and FFLG. A similar effect was detected in plasma urea concentrations. Pigs fed the 22% CP diets had an increase concentration of plasma urea compared to the pigs fed the 10, 14, and 18% CP diets. Gilts fed the 18% CP + AA had greater plasma urea concentration than gilts fed the 10% CP + AA and 14% CP + AA, indicating that the CP requirement of gilts in this experiment was > 18% CP and 0.92% total lysine. However, serum IGF-I concentrations were decreased in pigs fed the 10% CP, 10% CP + AA and 14% CP diets, indicating that the consumption of a diet below the pigs dietary crude protein requirement (18%) was associated with a reduction in IGF-I serum concentration. Also, serum IGF-I concentrations were reduced in gilts fed the low-protein, AA-supplemented diets which is supported by the reduction in IGF-I mRNA in semitendinosus and adipose tissue. However, this reduction in IGF-I serum concentrations or mRNA expression did not result in reduction in FFLG or carcass protein accretion rate. Thus, the reduction in serum IGF-I concentration in gilts fed the AA-supplemented diet was not severe enough to have an impact on lean growth rate or carcass protein accretion. Therefore, the results of the current experiment suggest that the feeding of low-protein, AA-supplemented diets does result in a decrease in serum IGF-I concentration and IGF-I mRNA expression in semitendinosus and adipose tissue, but this reduction in expression and serum concentration only partially explains growth rate and carcass composition results for gilts fed corn-soybean meal and low-protein, AA-supplemented diets.

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