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Summary and Implications

To find out why low-crude protein, amino acid-supplemented diets often reduce growing pig performance, we conducted two experiments. In the first experiment, a nitrogen balance trial, three standard corn-soybean meal diets and three corresponding low-crude protein, amino acid-supplemented diets were used. The diets were: 14% CP and 10% CP + AA, 16% CP and 12% CP + AA, and 18% CP and 14% CP + AA, fed to 12 (90 lb) gilts in three periods of 7 d each. The amino acids lysine, tryptophan, threonine and methionine were added to low-crude protein diets to reach the same total amount as that in their respective standard diet. All nitrogen balance variables studied were affected by the reduction of crude protein in the diets. For energy balance, only energy excreted in feces and the apparent digestibility of energy were affected by the concentration of crude protein in the diet. The second experiment was a growth performance trial, in which a standard corn-soybean meal, 16% crude protein, and five low-crude protein, amino acid-supplemented diets were fed to 36 (43 lb) gilts. The low-crude protein diets had 15, 14, 13, 12, and 11% crude protein, and were supplemented with crystalline lysine, tryptophan, threonine, and methionine to contain the same total concentration as that in the standard diet. There was no difference in average daily gain, average daily feed intake, feed/gain, longissimus muscle area, or average daily lean gain in gilts fed 12 to 16% crude protein diets. However, the 11% crude protein diet had negative effects on these variables. Plasma urea nitrogen increased as the crude protein increased from 11 to 16%. Backfat thickness was not affected by the crude protein concentration in the diet, but varied among the different diets. These results suggest that dietary crude protein can be reduced from 16 to 12% if amino acids are added, without affecting pig performance, and that this crude protein reduction can help reduce nitrogen excretion in the urine and feces.

Introduction

Modern pig production faces the dual challenges of producing pork efficiently and profitably and avoiding environmental contamination with waste materials, especially with nitrogen-containing products in manure. One method that can reduce nitrogen excretion is to reduce the protein concentration of the diet. However, when the crude protein is reduced from 16 to 12% for growing pigs, the reduction in essential amino acids can reduce growth performance. To avoid the reduction in growth performance, the limiting essential amino acids (generally lysine, tryptophan, threonine and methionine) are supplemented to meet the pig needs. Some research has shown no difference in growth, nitrogen retention, or carcass quality when pigs are fed reduced-protein, amino acid-supplemented diets. But, other research has shown reduced performance with the low-crude protein, amino acid-supplemented diets compared to the intact protein counterpart.

Materials and Methods

To find out why low-crude protein, amino acid-supplemented diets do not always produce the same results with growing pigs as standard corn-soybean meal diets, we conducted two experiments. In Experiment 1 (a nitrogen balance trial) 12 crossbred, 90-lb live weight, gilts were fitted with urinary catheters one week before the beginning of the experiment. The gilts were individually penned in metabolism crates and fed a specific sequence of diets during three periods of seven days each (one diet in each period). The diets (Table 1) were three standard corn-soybean meal diets with 14, 16, and 18% CP, and each one had a low-crude protein, amino acid-supplemented counterpart with 4% CP less: thus, they had 10, 12, and 14% CP, respectively. The amino acids added were lysine, tryptophan, threonine and methionine. These amino acids were added to restore the total concentration to have the same level as their corresponding standard diet. Nitrogen digestibility, biological value and nitrogen balance were determined by measuring nitrogen intake and nitrogen excretion in feces and urine. Average daily gain, feed intake and feed/gain also were calculated. Creatinine and urea in urine were determined using automated laboratory procedures. Gross energy was determined in feed, feces and urine to calculate the apparent energy balance.

In Experiment 2 (a growth performance trial), 36 crossbred gilts were individually penned and fed one of six diets for 35 days, starting at 43 lb and finishing at 103 lb. The experimental diets (Table 2) were: a control, standard corn-soybean meal, 16% CP diet and five low-crude protein, amino acid-supplemented diets, with 15, 14, 13, 12, and 11% CP, with crystalline amino acids added to equal those in the 16% CP diet. The amino acids added were lysine, tryptophan, threonine and methionine. Feed intake, average daily

Table 1. Diet composition in Experiment 1.[a]

	Crude protein concentration					
Ingredients, %	14%	10% + AA	16%	12% + AA	18%	14% + AA
Corn	79.60	91.06	74.33	85.73	69.21	80.63
Soybean meal (46.5% CP)	15.65	3.10	20.96	8.50	26.19	13.70
Dicalcium phosphate	1.25	1.55	1.20	1.50	1.10	1.40
Limestone	0.40	0.33	0.40	0.33	0.40	0.33
L-lysine•HCl	—	0.45	—	0.44	—	0.44
L-tryptophan	—	0.07	—	0.08	—	0.07
L-threonine	—	0.20	—	0.19	—	0.20
DL-methionine	—	0.13	—	0.13	—	0.13
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[b]	0.70	0.70	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10

[a]As-fed basis.
[b]Supplied per kilogram of diet: retinyl acetate, 3,086 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23 mg; choline chloride, 77 mg; vitamin B_{12}, 15.4 µg; ethoxyquin, 0.7 mg.
[c]Supplied (mg/kg of diet): Cu (as $CuSO_4$•$5H_2O$), 11; I (as $Ca[IO_3]_2$•H_2O), .22; Fe (as $FeSO_4$•H_2O), 110; Mn (as MnO), 22; Se (as Na_2SeO_3), .3; Zn (as ZnO), 110.

Table 2. Diet composition in Experiment 2.[a]

	Crude protein concentration					
Ingredients, %	11%	12%	13%	14%	15%	16%
Corn	88.17	85.59	82.755	80.15	77.71	74.81
Soybean meal (49.1% CP)	5.60	8.40	11.45	14.30	17.00	20.25
Dicalcium phosphate	1.47	1.41	1.35	1.28	1.24	1.16
Limestone	0.60	0.61	0.65	0.66	0.65	0.68
L-lysine•HCl	0.55	0.45	0.35	0.25	0.15	0.00
L-tryptophan	0.09	0.08	0.065	0.05	0.03	0.00
L-threonine	0.25	0.21	0.17	0.13	0.08	0.00
DL-methionine	0.17	0.14	0.11	0.08	0.05	0.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[b]	0.70	0.70	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10

[a]As-fed basis.
[b]Supplied per kilogram of diet: retinyl acetate, 3,858 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 19.3 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23 mg; choline chloride, 386 mg; vitamin B_{12}, 15.4 µg; ethoxyquin, 0.7 mg; folic acid, 1.5 mg; biotin, 0.077 mg.
[c]Supplied (mg/kg of diet): Cu (as $CuSO_4$•$5H_2O$), 11; I (as $Ca[IO_3]_2$•H_2O), .22; Fe (as $FeSO_4$•H_2O), 110; Mn (as MnO), 22; Se (as Na_2SeO_3), .3; Zn (as ZnO), 110.

Table 3. Growth performance results, Experiment 1.

	Crude protein concentration					
Variable	14% CP	10% + AA	16% CP	12% + AA	18% CP	14% + AA
ADG[1], lb	1.81	1.61	1.75	1.50	1.55	1.37
ADFI, lb	3.18	3.74	3.68	3.49	3.11	3.16
F/G	1.76	2.33	2.11	2.33	2.01	2.31

[1]ADG: Average daily gain.
ADFI: Average daily feed intake.
F/G: Average daily feed intake/average daily gain.

gain and feed/gain were measured weekly. Backfat thickness and longissimus muscle area were measured by ultrasound on the first and the last day of the experiment. Plasma urea nitrogen was measured the first, the fourteenth, and the last day of the experiment. Lean gain was determined using the National Pork Producers Council equations.

Results and Discussion

Experiment 1

There was no effect of the concentration of crude protein in the diet on average daily feed intake (ADFI), average daily gain (ADG) and feed/gain ratio (FG) (Table 3), probably because each experimental period was only one week. Initial body weight and ADFI were used as covariates for all nitrogen and energy (Table 4) balance variables. Nitrogen intake, nitrogen retention, apparent digestibility of nitrogen, apparent digestibility of energy, excretion of nitrogen in feces and urine, concentration of urea in urine, and excretion of energy in feces increased ($P < .05$) as the crude protein increased in the diet, regardless of the type of diet. Biological value, creatinine concentration in urine, other nitrogen in urine, nitrogen retention percentage, energy intake, energy retention, energy retention percentage, and energy excretion in urine were not affected by the concentration of crude protein. Additions of the four crystalline amino acids were not effective in increasing nitrogen retention to the same level that was achieved by the gilts fed the corresponding intact protein diets. Although there were no significant differences in energy retention, the low-crude protein diets had higher energy retention in the 16 vs 12 + AA and 18 vs 14 + AA comparisons, but not in the 14 vs 10 + AA comparison. These results suggest that nitrogen retention in growing pigs responds up to the highest concentration of crude protein fed in this experiment (18%) and that other factors in addition to the

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amino acid concentration of lysine, tryptophan, threonine and methionine affect the nitrogen retention.

Experiment 2

There were no differences among gilts fed 16, 15, 14, 13, or 12% CP diets (Table 5) in average daily gain, feed/gain, longissimus muscle area, or average daily lean gain. However, there was a reduction in the response of these variables in gilts fed the 11% crude protein diet compared to the other five treatments (quadratic effect of protein, $P \leq .05$). Average daily feed intake and backfat thickness were not affected ($P > .05$) by diet, but there was a tendency for feed intake to increase as the crude protein increased from 11 to 14% and decrease above this concentration. There is no apparent explanation for this trend, because the energy concentration was similar in all diets. There was a numerical increase in the fat thickness of gilts fed the 12% crude protein diet compared with all other diets. Plasma urea nitrogen increased as the crude protein increased in the diet from 11 to 16% (linear effect of protein, $P < .001$). These results confirm that crude protein can be reduced from 16 to 12% if amino acids are added to the diet without affecting pig performance, and that this reduction in CP in the diet can help to reduce the nitrogen excretion in the urine and feces (based on the reduction in plasma urea nitrogen as the crude protein was reduced in the diet). The reduction in crude protein to less than 12% reduced growth rate, possibly because other amino acids (e.g., isoleucine, valine, histidine) were deficient.

Table 4. Nitrogen (g/d) and Energy (Mcal/d) balance results, Experiment 1.

	Crude protein concentration					
Variable	14% CP	10% + AA	16% CP	12% + AA	18% CP	14% + AA
Nitrogen intake[a]	36.12	26.37	40.37	30.75	44.48	35.21
Nitrogen retention[a]	20.98	15.82	24.53	19.18	27.10	21.50
Nitrogen retention, %	58.82	58.01	60.89	62.41	59.77	60.86
Apparent digestibility of nitrogen, %[a]	88.16	83.20	87.99	85.64	87.06	86.51
Feces nitrogen[a]	4.36	4.46	4.80	4.44	5.81	4.73
Urine nitrogen[a]	10.78	6.09	11.04	7.12	11.56	8.98
Urea urine nitrogen[a]	7.48	3.95	7.86	4.86	9.22	6.17
Creatinine urine nitrogen	0.72	0.67	0.58	0.58	0.57	0.71
Other urine nitrogen	2.46	2.04	2.71	1.76	1.74	1.95
Energy intake	6.220	6.060	6.170	6.243	6.215	6.257
Energy retention	5.483	5.312	5.336	5.469	5.346	5.416
Energy retention, %	88.22	87.67	86.35	87.59	86.01	86.67
Apparent digestibility of energy, %[a]	90.17	88.73	88.48	89.72	87.62	88.80
Feces energy[a]	0.618	0.684	0.705	0.643	0.767	0.705
Urine energy	0.122	0.105	0.121	0.118	0.114	0.135

[a]Linear effect of protein, $P < .05$.

Table 5. Growth performance results, Experiment 2.[a]

	Crude protein concentration					
Variable	11%	12%	13%	14%	15%	16%
Average daily gain, lb[b]	1.29	1.80	1.85	1.86	1.71	1.70
Average daily feed intake, lb	3.36	3.72	3.94	4.03	3.65	3.56
Feed/gain[b]	2.60	2.07	2.13	2.16	2.14	2.10
Longissimus muscle area, in^2 [c]	2.81	3.35	3.35	3.35	3.36	3.45
Backfat thickness, in	0.41	0.56	0.45	0.46	0.46	0.43
Average daily lean gain, lb[b]	0.47	0.64	0.69	0.68	0.64	0.65
Plasma urea nitrogen, mg/100 ml [d]	2.57	3.94	5.10	6.80	7.61	10.45

[a]Six individually fed gilts per treatment, 35-d experiment, average initial weight 43 lb, average final weight 103 lb.
[b]Quadratic effect of protein, $P < .01$.
[c]Quadratic effect of protein, $P < .05$.
[d]Linear effect of protein, $P < .001$.

Summary

The results of the nitrogen balance and growth trials are not consistent. In the growth trial, we were able to reduce the crude protein percentage by four units along with appropriate amino acid supplementation and maintain performance. This was not the case in the nitrogen balance experiment in which, regardless of the initial protein percentage (14, 16 or 18%), the low-protein, amino acid-supplemented diets supported less nitrogen retention. The reasons for this inconsistency are unknown. Nitrogen retention is a more sensitive trait than average daily gain or average daily lean gain, but that does not fully explain the differences we observed. We are currently conducting additional experiments to investigate these issues.

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