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Summary and Implications

Research was conducted on commercial swine operations to determine whether plasma urea concentrations could be used as an indicator of the protein requirement of growing-finishing pigs. The research consisted of a 30-question survey and an on-farm visit to collect blood and feed samples. The survey included questions about genetics, nutrition, housing and health. Results showed that when plasma urea concentrations were analyzed across all phases of production, barrows had greater plasma urea concentrations than gilts. Plasma urea concentrations varied between the different phases of production, with nursery pigs having the lowest plasma urea concentrations, followed by growing and finishing pigs, respectively. An increase in dietary crude protein resulted in an increase of plasma urea in barrows and gilts in all phases of production. The comparison of dietary crude protein concentrations and age of the pigs at the time of blood collection indicates that the majority of the diets were over-formulated for crude protein. The effects of sex, crude protein, and phase of production on plasma urea concentrations in pigs raised on commercial operations were similar to those in a research setting. These results suggest that within an individual swine operation, plasma urea is a useful indicator of the protein requirement of growing-finishing pigs.

Introduction

The main goal of pork producers is to produce a high-quality product at the least cost. For producers to attain this goal and remain competitive in a changing industry, they must keep an open mind about changes that will improve the efficiency of their operations. To operate an efficient swine enterprise, producers must stay informed about new technologies in the areas of genetics, nutrition, management practices, facilities, and disease management. Implementing new technology from any one of these areas, or in combination, may alter the nutrient requirements of pigs in the operation. To monitor the protein requirement of pigs on a regular basis, a quick and reliable indicator of a pig's protein requirement would be an effective diagnostic tool for the producer and(or) nutritionist. This type of diagnostic tool would enable producers to formulate diets that accurately provide a pig with its dietary protein requirement and allow pigs to achieve their genetic potential for lean growth. The net result of a more precise feeding program would be decreased costs, because of an increase in the efficiency of nutrient use by the pig.

Diets that supply crude protein in excess of the requirements for maintenance and protein accretion are inefficient because excess protein nitrogen is excreted in the urine in the form of urea. Pigs have little ability to store excess amino acids independent of muscle protein. Thus, amino acids in excess of the requirement are catabolized (used for energy or fat deposition), and the nitrogen (NH_3) is converted to urea, causing in some instances a sharp rise in plasma urea concentrations. Researchers have reported that dietary lysine concentrations above the requirement result in an increase in plasma urea concentration in growing and finishing pigs. A similar plasma urea pattern has been observed in pigs when dietary crude protein is supplied in excess of the requirement. These data suggest that feeding crude protein

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Table 1. Average concentrations of plasma urea, dietary crude protein concentrations, and age of pigs at the time of blood collection for each farm.

	Farm											
Item	A	B	C	D	E	F	G	H	I	J	K	L
Nursery barrows												
PUC[a], mg/dL	29.47	20.82	28.00	—	—	—	19.52	—	19.71	16.26	31.72	—
CP[b], %	20.78	20.46	22.69	—	—	—	16.11	—	21.48	17.15	22.14	—
Age, weeks	9	4	8	—	—	—	7	—	6	8	8	—
Nursery gilts												
PUC, mg/dL	33.90	17.76	23.00	—	—	—	18.70	—	21.39	16.79	25.28	—
CP, %	20.78	20.46	22.69	—	—	—	16.11	—	21.48	17.15	22.14	—
Age, weeks	9	4	8	—	—	—	7	—	6	8	8	—
Growing barrows												
PUC, mg/dL	31.41	31.77	—	22.12	28.60	44.74	32.10	39.37	30.53	21.04	21.86	31.66
CP, %	17.77	17.78	—	20.21	17.78	18.99	15.39	18.38	17.54	14.91	13.72	19.99
Age, weeks	17	14	—	13	12	13	15	11	15	17	16	10
Growing gilts												
PUC, mg/dL	32.71	31.89	—	24.45	35.63	34.29	26.85	30.21	31.01	18.42	23.17	27.94
CP, %	16.69	17.85	—	20.21	19.67	18.89	17.09	18.67	17.90	14.91	15.55	19.99
Age, weeks	17	14	—	13	12	13	15	11	15	17	16	10
Finishing barrows												
PUC, mg/dL	38.47	36.47	30.94	37.51	41.95	42.44	—	—	39.46	28.49	20.11	25.23
CP, %	15.79	16.05	12.54	17.66	19.36	15.46	—	—	14.71	13.31	12.76	14.55
Age, weeks	24	22	24	20	19	22	—	—	24	21	20	23
Finishing gilts												
PUC, mg/dL	37.67	30.57	28.02	31.82	32.73	36.66	—	—	36.91	22.97	24.46	24.98
CP, %	16.47	16.05	12.54	17.66	18.75	15.26	—	—	15.51	13.31	16.01	14.55
Age, weeks	24	22	24	20	19	22	—	—	24	21	20	23

[a]PUC = plasma urea concentration.
[b]CP = dietary crude protein.

levels greater than the requirement result in an excess of amino acids that must be catabolized and removed from the body.

Plasma urea concentrations have been used by researchers as an indicator of a pig's protein and amino acid requirements. Research projects conducted at the University of Nebraska-Lincoln have demonstrated that changes in plasma urea concentrations in response to changes in the dietary protein level can be used to determine the protein requirement of pigs that possess different genetic potentials to deposit lean. These studies have shown that plasma urea concentrations could also be used to determine the time point at which the protein level should be changed throughout the growing-finishing period. The plasma urea concentration response agreed well with the growth and carcass data, and it seems that plasma urea concentrations may reflect changes in the pig's protein requirement more precisely than do standard growth and carcass data. Therefore, the use of plasma urea concentrations as a tool to help producers precisely formulate diets throughout the growing-finishing period provides the pork industry an alternate and simple method of determining requirements for dietary protein. Thus, the current research was designed to investigate whether plasma urea concentrations can be used as an on-farm index of the protein requirements of different populations of pigs.

Procedures

The research included two parts. Part one was a 30-question survey that was completed by the producer. The survey included four major sections with questions about genetics, nutrition, housing, and health. The genetics section asked questions about seedstock suppliers, replacement gilts, determination of nutrient requirements, and lean gain potential. This section also inquired about carcass data and production records. Information acquired included backfat depth, loin depth, percent yield and lean, hot carcass weight, average weight at the beginning of the growing-finishing period, average slaughter weight, and days from start of the growing-finishing period to slaughter. From the carcass and production data, an average fat-free lean gain was calculated for each operation. Nutrition questions included protein and lysine concentrations fed in each diet, the amount of each diet provided, separate-sex feeding, and type and amount of antibiotics used in the diets. The housing section questions pertained to type of facilities (confinement or outdoors), ventilation, space/pig, type of feeders, and space/pig for feeders and waterers. The health section included questions about facility biosecurity, pig flow, pig grouping, facilities cleaning, antigen exposure, visual symptoms of illness, and percent death loss.

The second part of this research was an on-farm visit. During the on-farm visit any questions that the producer had about the questionnaire were answered. Blood samples (plasma and serum) were collected from 10 barrows and 10 gilts within each growth phase (nursery, growing, and finishing). A diet sample was collected for each group of pigs sampled. The diet sample was analyzed for crude protein and plasma samples were analyzed for urea con-

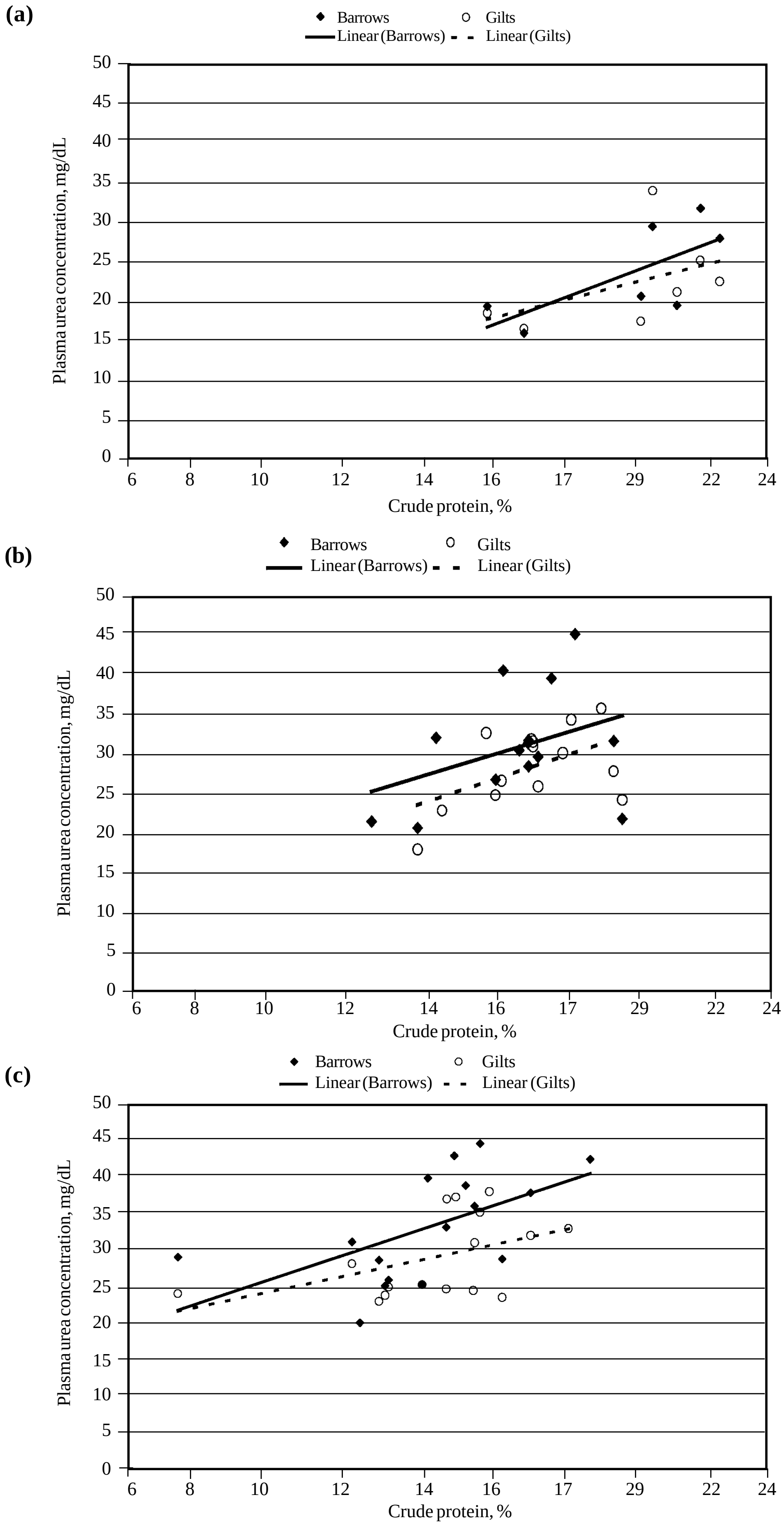

Figure 1. The response of plasma urea concentration to changes in dietary crude protein; a) nursery; b) growing; c) finishing. Each data point represents an individual operation; a) nursery, n=7; b) growing, n=14; c) finishing, n=16.

centration.

Data were analyzed using the GLM procedure of SAS (1996). The main effects in the statistical model were sex (barrows and gilts) and phase (nursery, growing, and finishing). Regression equations for plasma urea concentration on dietary crude protein concentration for barrows and gilts during each phase of production were analyzed to determine the amount of variation in plasma urea concentration that was accounted for by a change in dietary crude protein. In all statistical analyses, farm was the experimental unit.

Results

Plasma urea concentration, dietary crude protein concentration, and age of the pigs at the time of blood collection are shown in Table 1. Plasma urea concentrations were greater ($P < 0.05$) in barrows than in gilts in all phases of production. There was an effect of phase of production ($P < 0.01$), with the finishing pigs having the greatest plasma urea concentration followed by the growing and nursery pigs, respectively. An increase in the concentration of dietary crude protein increased ($P < 0.01$) the concentration of plasma urea (Figure 1). Gilts consistently had lower plasma urea concentrations than barrows, especially when dietary protein concentrations were high. This lower plasma urea concentration indicates that gilts have better utilization of protein for lean muscle deposition compared to barrows. The 1998 NRC model was used to predict the crude protein requirement of pigs from each farm and phase of production using data shown in Table 2. These predicted crude protein requirements were compared to the analyzed crude protein concentrations in the diet. During the late nursery phase, six to eight weeks of age, some diets were providing approximately two percentage units more crude protein than required by the pig. Analyzed crude protein concentrations indicated that many pigs in the growing, nine to 17 weeks of age, and finishing, 17 to 24 weeks of

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Table 2. Production data from each farm surveyed and sampled.

Item	A	B	C	D	E	F	G	H	I	J	K	L
	Farm											
Number of pigs sold/year	2,400	2,400	1,300	2,400	1,250	1,200	1,200	25,000	2,300	9,000	8,000	285,000
Backfat, in	.75	.72	.76	.74	.82	.77	.79	.74	.70	.66	.89	.74
Loin depth, in	2.50	2.60	2.68	2.43	2.60	2.47	2.51	2.50	2.65	2.27	—	2.3
Percent lean	54.00	55.20	54.00	55.00	54.00	54.00	53.90	55.00	54.50	55.50	—	53.50
Percent yield	75.00	76.80	75.90	75.40	76.10	75.00	75.09	75.00	75.50	76.60	74.74	75.85
Hot carcass weight, lb	180	199	204	200	214	190	198	193	201	192	197	183
Starting weight, lb	11	11	11	11	11	11	65	11	11	12	12	45
Slaughter weight, lb	240	260	272	265	279	253	266	257	266	243	253	242
No. of days in finishing period	172	164	168	182	175	170	112	166	163	161	—	122
Fat-free lean gain, lb/day[b]	.53	.63	.62	.56	.62	.56	.70	.60	.63	.62	—	.64
Separate-sex feeding?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Space/pig[a] (Nursery)	3.5	—	4.0	3.0	—	—	3.0	—	3.5	3.0	2.5	2.8
Space/pig (Growing)	6.0	—	8.0	5.0	8.4	8.0	7.8	—	8.0	3.5	12.0	7.8
Space/pig (Finishing)	6.0	—	8.0	10.0	8.4	8.0	7.8	—	8.0	4.0	12.0	7.8
Percent death loss (Nursery)	2.5	1.0	2.5	2.5	4.5	—	1.0	—	2.5	2.5	1.0	2.5
Percent death loss (Growing/Finishing)	4.5	4.5	2.5	2.5	2.5	2.5	2.5	—	2.5	2.5	2.5	4.5

[a]Space/pig = ft^2/pig.
[b]FFLG was calculated by using the equation:

$$\frac{\text{(Final carcass fat-free lean, lb)} - \text{(Initial carcass fat-free lean, lb)}}{\text{Days from initial to final weight}}$$

Final carcass fat-free lean (lb) = 0.95 x (percent lean, 5% fat basis x hot carcass weight, lb)
Initial fat-free lean (lb) = 0.95 x [-3.65 + (.418 x live weight, lb)]

age, phases were potentially overfed protein by as much as three percentage units.

Regression equations (Table 3) for the effect of crude protein on plasma urea concentration (depicted in Figure 1) were calculated for each sex and phase of production. Results show that the change in crude protein accounted for 14 to 50% of the variation in plasma urea concentration.

Table 3. Regression equation of plasma urea concentration on dietary crude protein for barrows and gilts during each phase of production, equations are represented in Figure 1.

Item	N-G	N-B	G-G	G-B	F-G	F-B
	Phase of Production and Gender[a]					
a[b]	1.1243	1.6727	1.5929	1.4255	.9877	1.5419
b	-0.2587	-10.0030	.0485	5.9710	14.1490	10.1990
R square	.23	.50	.27	.14	.22	.32

[a]N-G = nursery gilts; N-B = nursery barrows; G-G = growing gilts; G-B = growing barrows; F-G = finishing gilts; F-B = finishing barrows.
[b]Equation: Y = ax + b ; Y = plasma urea concentration (mg/dL); x = dietary crude protein concentration (%).

Survey results from each farm are shown in Table 2. Production data from the operations showed that approximately 28,000 pigs/year (range: 1,200 to 285,000 pigs/year) were sold per farm. Lean gain potential on most farms was considered to be in the high category (> .72 lb/d). Data from the kill sheets show that the average backfat depth was .76 inches and loin depth was 2.50 inches. The average percent lean was 54.4, yield was 75.6 %, and hot carcass weight was 195 lb. Weight at the beginning of the growing-finishing period averaged 19 lb, average weight at slaughter was 258 lb, and the number of days from the start of the finishing period to slaughter was 160. Fat-free lean gain calculated from the production and carcass data averaged .61 lb/d. Separate sex feeding was used on most farms. The majority of pig flow was all-in-all-out in the nursery and growing-finishing facilities, and the majority of pigs were raised in mechanically ventilated confinement buildings. Space per pig averaged 3.16 ft^2 in the nursery and 7.75 ft^2 in the growing-finishing phase. All facilities were routinely high-pressure washed and disinfected between pig groups. Mycoplasmal hyopneumonia and Porcine Respiratory and Reproductive Syndrome (PRRS) were the two main disease concerns. Death loss in the nursery and growing-finishing periods averaged 2.5%.

Production and carcass data acquired from the producers indicate they are producing a lean pork product. The use of separate sex feeding on most farms allows producers to accurately provide the nutrients required to maximize lean growth without overformulating the diet. The space per pig in the nursery and growing-finishing facilities was adequate, therefore growth (lean tissue gain) was not affected by crowding. The low mortality rate can be attributed to good management, all-in-all-out pig flow, and the cleaning and disinfecting of facilities between pig groups. A major concern is the difference between the lean gain potential as estimated by individual producers and the calculated fat-free lean gain of the pigs. The difference between the lean gain potential (> .72

lb/d) and the average calculated fat-free lean gain (.61 lb/d) is 15%. Therefore, if the producers were formulating their diets based on the lean gain potential of their pigs and not the actual fat-free lean gain the diets would be over-formulated for dietary crude protein. This may explain why some diets were over-formulated for dietary crude protein by as much as three percentage units. In addition, research has shown that when pigs are fed a corn-soybean meal diet with no crystalline amino acids to meet the pig's crude protein requirement the plasma urea concentration should be approximately 25 mg/dL. In many cases, the plasma urea concentrations shown in Table 1 exceed 25 mg/dL, further supporting the finding that most diets were over-formulated for crude protein.

Conclusions

Results from this on-farm study indicate that the relationship between plasma urea concentration and dietary crude protein is similar to the relationship established in our research facilities. Plasma urea concentrations have the potential to be used as a means of selecting replacement boars and gilts with a high potential for lean growth. Animals would be selected for a low plasma urea concentration when fed a diet formulated to meet their dietary protein requirement. By using this technology, a producer would select animals with a more efficient utilization of dietary protein and an increase in lean muscle accretion. This technology also has the ability to help producers make management decisions on their farms. Producers could use this technology to determine if the environment, diet, facility or a management practice is limiting the lean growth potential of their pigs. These results also indicate that plasma urea concentration has the potential to be used as an indicator of the protein requirement of growing-finishing pigs. The use of plasma urea concentrations to determine the protein requirement would be less costly and time consuming than the traditional feeding and carcass analysis experiments used to identify protein requirements for growing-finishing pigs. However, nutrient requirements for each phase of production on each operation are not the same because of differences in genetics, management, disease, and facilities between operations. Therefore, this approach may assist producers in determining the correct time point to change the nutrient density in the diet to meet the protein requirement more accurately. Also, this methodology may help producers and nutritionists clearly identify instances where excess dietary protein is provided.

A special thank-you goes out to all of the producers involved in this experiment. We appreciated your willingness to participate in this experiment, taking time to fill out the survey, and allowing us to bleed pigs on your operation. Without you this experiment would not have been possible.

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