Blood Urea Nitrogen as an Index of Feed Efficiency and Lean Growth Potential in Growing-Finishing Swine

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ABSTRACT : Five experiments were conducted to evaluate blood urea nitrogen (BUN) as a potential index of feed efficiency (G/F) and lean growth in growing-finishing pigs. Exp. 1 was conducted to examine the relationship between feeding protocol and BUN values. Fasted-refed pigs exhibited BUN peaks 3 h post-prandially while those given *ad libitum* access to diet had inconsistent BUN patterns in 10 h blood sampling with an 1 h interval. In Exp. 2 and 3, it was revealed that the peak BUN values were negatively correlated ($p<0.01$) with G/F in both barrows and gilts at 20 kg body weight (BW) and 50 kg to 90 kg BW. In Exp. 4, it was found that BUN values between 55 kg and 70 kg BW, when lean gain is maximized, were best correlated with average daily lean gain (ADLG). In Exp. 5, 18 barrows and 21 gilts were used to examine the relationship between BUN values at 65 kg BW and ADLG from birth to market weight. The BUN values at 65 kg BW and ADLG were negatively correlated ($p<0.01$) in both genders. These experiments demonstrated that there was a correlation between peak BUN values, and G/F and ADLG under specific circumstances. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 6 : 811-816*)

Key Words : Pigs, Blood Urea Nitrogen, Lean Growth, Feed Efficiency

INTRODUCTION

Urea is the main nitrogenous end product arising from the catabolism of amino acids that are not used in biosynthetic reactions in mammals. Urea production should reflect not only alterations in the dietary intake of protein and patterns of utilization of amino acids but also an animals ability to retain dietary nitrogen in the body. It has been found that BUN is related directly to protein intake and inversely to protein quality (Eggum, 1970; Orok and Bowland, 1975; Bassily et al., 1982). The BUN has been used to establish amino acid requirements (Lewis and Speer, 1973; Robles-Cabrera and Speer, 1983; Hahn et al., 1995).

Barrows treated with porcine somatotropin (pST) show a linear depression of BUN in a dose-dependent manner. Unknown pST activity could be predicted by BUN differences before and after pST treatment (Miller and Baldwin, 1989a). The same researchers also showed that BUN was more highly correlated with feed conversion ratio than insulin-like growth factor-I (IGF-I) or insulin (Miller and Baldwin, 1989b). Also, Gourley and Zimmerman (1993) demonstrated that BUN of pigs in lean strains was highly correlated with lean estimates but poorly correlated in fatter strains.

The objectives of this study were to establish the blood sampling method for the BUN assays and to understand a relationship between BUN concentration and feed efficiency and lean growth in swine.

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MATERIALS AND METHODS

In Exp. 1, four intact males, four barrows and four gilts (weight=40.75±0.95 kg) from Pig Improvement Company (PIC, Camborough 15) were used to examine the effect of feeding protocol on BUN values. Pigs were randomly assigned to experimental treatments from these blocks. Treated animals were divided according to gender, i.e., intact males, castrated and gilts. Two pigs of each gender either were given *ad libitum* access to diet or were fasted for 14 h, then allowed to consume diet for an hour. The percentage composition and calculated analysis of test diet is shown in table 1. All pigs were bled hourly for 10 h post-prandially. To minimize the possible stress during the bleeding, animals were trained for 5 days before bleeding and the blood samples were obtain from the ear veins. A three to five mL blood was obtained for the BUN assays. The blood samples were centrifuged at 2,000×g for 20 min and the harvested plasma was frozen at 20℃ until analysis.

The Exp. 2 was designed to examine the relationship between BUN values and feed efficiency with eight barrows and eight gilts (initial body weight=20.6±3.0 kg) from PIC (Camborough 15). Animals were individually penned and fed a corn-soybean meal-based diet including 16% crude protein and 0.85% lysine (grower diet in table 2). After a 4-d adaptation period, pigs were fasted for 14 h (as described in Exp. 1) and subsequently fed a 125

Table 1. Percentage composition and calculated analysis of the test diet used for blood urea nitrogen determinations

	%
Ingredients:	
Corn	67.22
Dehulled soybean meal	1.49
Fish meal, menh.	7.00
Plama protein (AP-820)[a]	5.00
Casein, erie	7.50
Sucrose	10.00
Dicalcium phosphate	0.97
Ground limestone	0.27
Vitamin premix[b]	0.20
Trace-mineral salt[c]	0.35
Calculated analysis:	
Crude protein	22.00
Lysine	1.43
Ca	0.65
P	0.55
DE (Mcal per kg diet)	3.50
ME (Mcal per kg diet)	3.31

[a] Contains 70.00% crude protein, 13.00% ash, 2.00% fat, 0.14% calcium, 0.13% phosphorus, 3.01% alanine, 6.36% aspartate, 4.79% arginine, 2.24% cystine, 3.70% phenylalanine, 2.44% glycine, 8.85% glutamate, 2.50% histidine, 1.96% isoleucine, 5.56% leucine, 6.10% lysine, 0.53% methionine, 4.09% proline, 3.86% serine, 4.13% threonine, 1.33% tryptophan, 3.50% tyrosine and 4.12% valine (American Protein Corporation, Ames, IA, USA).

[b] Provided per kilogram of diet: 6,600 IU vitamin A, 660 IU vitamin D_3, 88 IU vitamin E, 4.4 mg vitamin K, 0.0352 mg vitamin B_{12}, 8.8 mg riboflavin, 24.2 mg D-pantothenic acid, 33.0 mg niacin and 330 mg choline chloride.

[c] Provided per kilogram of diet: 20.05 mg Mn, 90.38 mg Fe, 100.58 mg Zn, 8.09 mg Cu, 0.35 mg I and 0.30 mg Se.

g test diet (table 1) containing 27.5 g crude protein. They were then bled at 2 h, 3 h and 4 h after the meal to secure peak BUN values as we found the highest BUN levels between 2 h and 4 h after feeding in Exp. 1. During the 20-day experiment period, individuals were observed and orts were collected, dried and weighed to correct the feed intake each day. Body weights and feed intake were measured every five days.

The Exp. 3 was conducted to examine the relationship between BUN values and feed efficiency from approximately 50 kg body weight to 90 kg body weight with 20 barrows and 19 gilts (initial body weight=49.8±2.0 kg; final body weight=91.4±4.2 kg) from PIC (Camborough 15). Animals were individually penned and fed a corn-soybean meal-based diet including 15% crude protein and 0.75% lysine (finisher

Table 2. Percentage composition and calculated analysis of experimental diets in Exp. 2, 3, 4 and 5

	Grower	Finisher
Ingredients (%):		
Corn	75.47	80.45
Dehulled soybean meal	20.40	17.37
Soybean oil	1.50	-
Lysine-HCl	0.03	0.01
Dicalcium phosphate	1.15	0.90
Ground limestone	0.72	0.77
Vitamin premix[a]	0.20	0.20
Trace-mineral salt[b]	0.35	0.30
ASP-250[c]	0.20	-
Calculated analysis		
Crude protein	16.00	15.00
Lysine	0.85	0.75
Ca	0.65	0.60
P	0.55	0.50
DE (Mcal per kg diet)	3.53	3.48
ME (Mcal per kg diet)	3.38	3.34

[a] Provided per kilogram of diet: 6,600 IU vitamin A, 660 IU vitamin D_3, 88 IU vitamin E, 4.4 mg vitamin K, 0.0352 mg vitamin B_{12}, 8.8 mg riboflavin, 24.2 mg D-pantothenic acid, 33.0 mg niacin and 330 mg choline chloride.

[b] Provided per kilogram of diet grower: 20.05 mg Mn, 90.38 mg Fe, 100.58 mg Zn, 8.09 mg Cu, 0.35 mg I and 0.30 mg Se; Provided per kilogram of diet finisher: 17.18 mg Mn, 77.47 mg Fe, 86.21 mg Zn, 6.93 mg Cu, 0.30 mg I and 0.26 mg Se.

[c] Supplied per kilogram of diet: 110 mg chlortetracycline, 110 mg sulfamethazine and 55 mg penicillin (American Cynamid Co., Princeton, NJ, USA).

diet in table 2). After a 5-d adaptation period, pigs were fasted for 14 h (as described in Exp. 1) and subsequently fed a 310 g test diet (table 1) containing 68.1 g crude protein. They were then bled at 2 h, 3 h and 4 h after the meal to secure peak BUN values. The bleeding time was decided based on the BUN values from Exp. 1. Individual animals were observed and orts were collected, dried and weighed to correct the feed intake each day for the experiment period. Body weights and feed intake were measured weekly.

In Exp. 4, ten PIC crossbred barrows (initial body weight=21.3±0.3 kg) and ten gilts (initial body weight=21.9±0.5 kg) were used to examine the relationship between BUN values at five different body weights and lean gain from birth to an average of 116.46 kg body weight. All pigs were individually penned and given *ad libitum* access to the diet shown in table 2. The experimental diets were formulated to exceed NRC (1988) requirements. They were serially bled as described in Exp. 2 at the following average body weights: 21.6 kg, 36.3 kg, 55.5 kg, 77.0 kg and 116.5 kg. The quantity of the refeeding test diet was

calculated from 0.58 g N per kg $BW^{0.75}$. Plasma samples were harvested as described in Exp. 1 and used for BUN, creatinine and protein assays. All pigs at termination of the experiment were slaughtered and standard carcass measurements were taken to estimate the lean body mass by using NPPC (1991) formula. Average daily lean gain from birth to termination was calculated by dividing the lean body mass at termination by age of the individual animals.

In Exp. 5, 19 barrows and 21 gilts (initial body weight=19.3±0.8 kg) from PIC (Camborough 15) were used to examine the relationship between BUN at 65.0 kg body weight and lean gain from birth to market weight (111.2±3.8 kg). Animals were individually penned and fed corn-soybean meal-based diets. The experimental diets are shown in table 2. All pigs were given *ad libitum* access to the diet and water. Pigs were bled at average 65.0 kg after 14 h fasting and refeeding the test diet (table 1) as described in Exp. 2. The 377 g of the test diet included 82.9 g crude protein. Plasma samples were harvested as described in Exp. 1 and used for BUN assay. All pigs at termination of the experiment were slaughtered and standard carcass measurements were taken to estimate the lean body mass by using NPPC (1991) formula. Average daily lean gain from birth to termination was calculated by dividing the lean body mass at termination by age.

The BUN concentrations of individual samples were measured on an autoanalyzer (Boehringer Mannheim Diagnosis, Indianapolis, IN. USA) using a method based on procedure of Skeggs (1957) and Marsh et al. (1957). Plasma samples were also analyzed for creatinine by colorimetry, based on Peters (1942). The protein of plasma samples was measured using Biuret method (Gornall et al., 1949).

Data on BUN, creatinine, plasma protein, BUN: plasma protein ratio of barrows and gilts were analyzed jointly and separately by analysis of covariance with the GLM procedure of SAS (1985). The BUN data were plotted against feed efficiency in Exp. 2 and Exp. 3 and average daily lean gain in Exp. 4 and Exp. 5 using a simple linear equation.

RESULTS AND DISCUSSION

Historically, swine feeding programs have been based on empirically derived national standards for nutrient requirements (NRC, 1988). A key assumption of the approach is that all pigs are similar to those used experimentally to establish the requirements. There is a mounting evidence the populations of pigs differ greatly in capacity for lean growth and, consequently, the dietary need for amino acids to support that growth (Sauber et al., 1998; Friesen et al., 1995; Bikker et al., 1994). Unfortunately, there is not a technique for rapid, effective estimation of lean growth in the living animals.

In Exp. 1, fasted and refed pigs (intact males, barrows and gilts) exhibited BUN peaks approximately 3 h post-prandially while those given *ad libitum* access to diet had inconsistent BUN patterns (figure 1). Because of the strong association between BUN concentration and nitrogen intake, it appeared necessary to standardize both nitrogen intake and amino acid profile of the test diet. And, blood samples should be taken under fixed conditions. This experiment also demonstrated that the peak BUN values caused by the last meal (test diet) could be obtained by fasting for enough time (14 h in this experiment) to lessen BUN concentration to the basal level and sampling at approximately 3 h after refeeding. More than 75% of the peak BUN values in Exp. 1, Exp. 2, Exp. 3, Exp. 4 and Exp. 5 were shown at 3 h post-prandially.

Peak BUN values were negatively correlated ($p<0.01$) with feed efficiency (G/F) at approximately 20 kg body weight in both barrows and gilts in Exp. 2. The linear equations for barrows and gilts were $Y=0.609 - (1.692\times10^{-2})X$ ($r^2=0.807$) and $Y=0.577 - (1.330\times10^{-2})X$ ($r^2=0.891$), respectively (figure 2). Also, in Exp. 3, BUN values at approximately 50 kg body weight and feed efficiency from approximately from 50 kg to 90 kg body weight had a negative correlation ($p<0.01$). The linear equations for barrows and gilts were $Y = 0.465 - (1.348\times10^{-2})X$ ($r^2=0.553$) and $Y=0.484$ $(1.510\times10^{-2})X$ ($r^2=0.703$), respectively (figure 3). These results agree with Hahn et al. (1995) who reported that BUN decreased linearly ($p<0.01$) as G/F increased ($r^2=0.57$ for barrows and 0.66 for gilts) for the same body weight range as this experiment.

Miller and Baldwin (1989a, b) reported that PST-treated pigs showed a linear depression of BUN in a dose-dependent manner. They also reported that the BUN is more highly correlated with G/F than insulin-like growth factor-I (IGF-I) or insulin. The present study indicated that the peak BUN values must be correlated with lean gain because the lean gain should be well correlated with G/F.

In Exp. 4 with serial blood sampling from approximately 20 kg body weight to slaughter weight, estimated average daily lean gain (ADLG) from birth to market weight was best correlated with the BUN:plasma protein ratio (BUN:P) at 77.00 kg body weight in barrows ($r^2=0.524$; $p<0.05$) and 55.47 kg body weight in gilts ($r^2=0.717$; $p<0.01$). The correlation between ADLG and BUN:P at different body weight were lower and are shown in table 3. However, there was no significant correlation between ADLG and creatinine values, or creatinine:plasma protein ratio. The ADLG might be best correlated with the BUN:P at a time when pigs have a maximal lean gain.

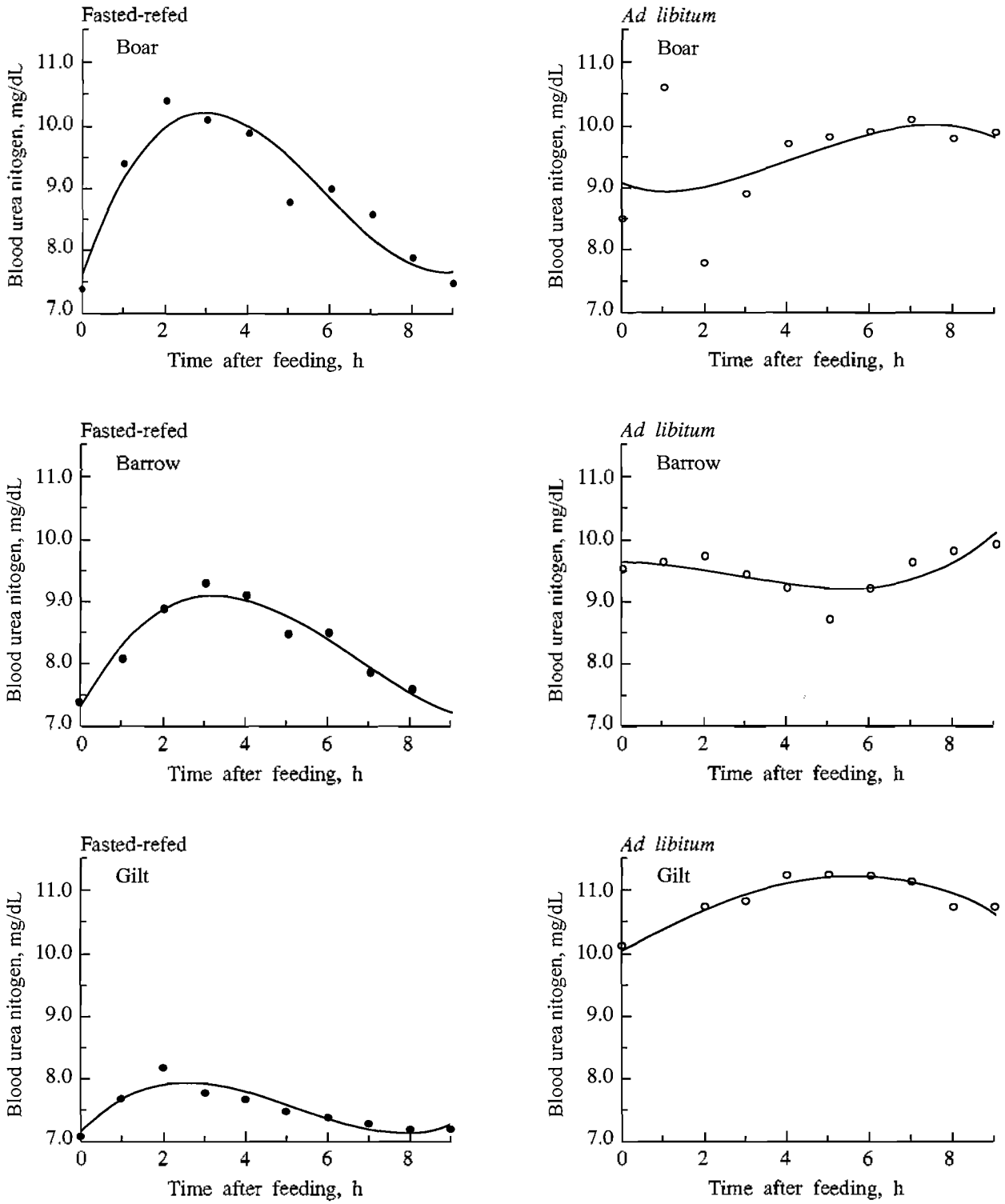

Figure 1. Examples of polynomial plot of blood urea nitrogen for 10 h as a function of time after refeeding in Exp. 1. Fasted-refed pigs (filled symbol) were fasted for 14 h, then allowed to eat for 1 h before sampling. *Ad libitum* pigs (empty symbol) were given *ad libitum* access to feed and bled at the same time as fasted-refed pigs

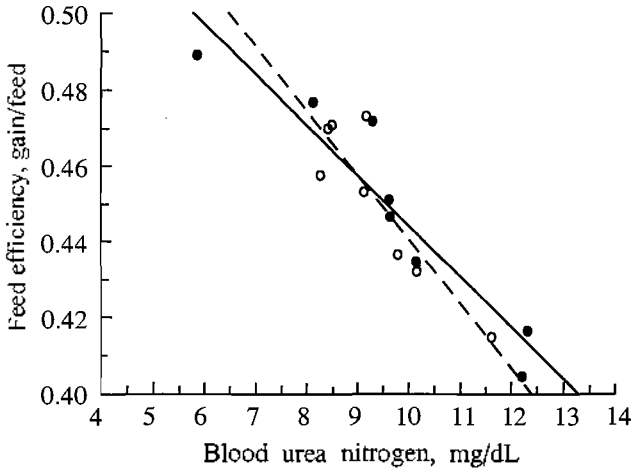

Figure 2. The linear relationship of peak blood urea nitrogen values and feed efficiency at 20 kg body weight in Exp. 2. Pigs were fasted for 14 h and allowed to consume 125 g of test meal containing 27.5 g crude protein, then bled at 2, 3 and 4 h after refeeding. Linear equations for barrows (empty symbol and dashed line) and gilts (filled symbol and solid line) are $Y=0.609-(1.692\times10^{-2})X$ ($r^2=0.807$) and $Y=0.577-(1.330\times10^{-2})X$ ($r^2=0.891$), respectively.

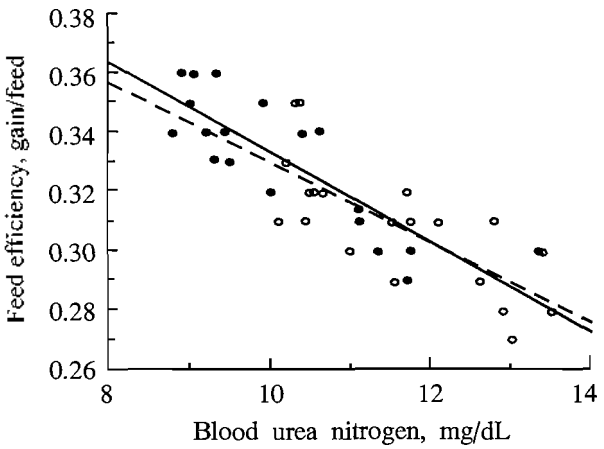

Figure 3. The linear relationship of peak blood urea nitrogen values and feed efficiency from approximately 50 kg to 90 kg body weight in Exp. 2. Pigs were fasted for 14 h and allowed to consume 310 g of test meal containing 68.1 g crude protein, then bled at 2, 3 and 4 h after refeeding. Linear equations for barrows (empty symbol and dashed line) and gilts (filled symbol and solid line) are $Y=0.465-(1.348\times10^{-2})X$ ($r^2=0.553$) and $Y=0.484-(1.510\times10^{-2})X$ ($r^2=0.703$), respectively.

Table 3. Correlation coefficients of peak blood urea nitrogen:plasma protein ratio to average daily lean gain from birth to termination at different body weights[a]

BW (kg)	21.3	36.3	55.5	77.0	116.5
Barrows	0.025	0.014	0.278	0.524	0.328
Gilts	0.018	0.425	0.717	0.467	0.409

[a] Pigs were fasted for 14 h and fed test diet (0.58 g N per kg $BW^{0.75}$), then bled 2 h, 3 h and 4 h after refeeding.

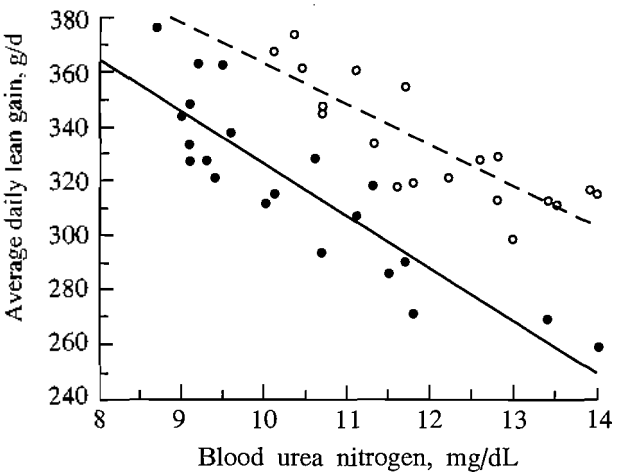

Figure 4. The linear relationship of peak blood urea nitrogen values and average daily lean gain (g/d) from birth to market weight in Exp. 5. Pigs at approximately 65 kg body weight were fasted for 14 h and allowed to consume 377 g of test meal containing 82.9 g crude protein, then bled at 3 h after refeeding. Linear equations for barrows (empty symbol and dashed line) and gilts (filled symbol and solid line) are $Y=510.93-14.77X$ ($r^2=0.706$) and $Y=516.65-19.01X$ ($r^2=0.781$), respectively.

As shown in figure 4, the BUN values at 65 kg body weight and average daily lean gains from birth to market weight were negatively correlated. The linear equations for barrows and gilts were $Y=510.93-14.77X$ ($r^2=0.706$) and $Y=516.65-19.01X$ ($r^2=0.781$), respectively. Hahn et al. (1995) also reported that BUN decreased linearly ($p<0.01$) as lean gain estimates increased ($r^2=0.67$ for barrows and 0.71 for gilts).

In the present study, gilts showed better correlation between BUN and lean gain and feed efficiency than barrows. Gourley and Zimmerman (1993) reported that BUN in lean strains was highly correlated with lean estimates but lowly correlated in fatter strains. They indicated the possibility that the diet supplied excess protein and amino acids for fatter strains. The excess

may have made BUN less responsive. The present study showed that BUN in barrows tended to be higher than that in gilts at 55.47 kg and 116.46 kg body weight in Exp. 4 (data not shown).

IMPLICATIONS

These results demonstrated that BUN values are well correlated with lean gain and feed efficiency in pigs if blood samples are taken under fixed conditions. Blood sampling and BUN assessment after consumption of a known and equal quantity of a test meal offers potential for determining lean gain potential of pigs. Our data also indicate that BUN values obtained when pigs show maximal lean deposition are best correlated with lean gain for the entire production period. Therefore, peak BUN values at approximately 60 kg to 70 kg body weight under specific circumstances are useful to estimate lean gain potential and select pigs for lean gain.

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