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Interaction of dietary energy and protein on growth performance, carcass characteristics and digestibility in finishing barrows when fed at a constant digestible lysine to metabolizable energy ratio

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ABSTRACT

The objective of this study was to determine the performance response to changes in dietary fat, protein, and fiber content in finishing barrows while maintaining a constant apparent ileal digestible (AID) Lys to metabolizable energy (ME) ratio (AID Lys:ME). The experiment was conducted in 2 trials, each containing 25 individually penned pigs. In both trials, barrows (initial wt = 85.3 kg) were blocked by weight and assigned to one of five experimental diets (0.40, 0.44, 0.48, 0.52, and 0.56% digestible Lys) with a constant AID Lys:ME (1.44 g/MCal). Lysine content was changed by altering the proportions of corn and soybean meal and energy was altered by the addition or removal of cellulose and fat. Diets contained 0.2% titanium dioxide as a digestibility marker. Pigs were fed experimental diets for 28 d, and body weights, feed intakes, and ultrasound measurements of tenth rib backfat (BF) and loin eye area (LEA) were recorded on d 14 and 28. Blood samples were taken on d 28 to determine serum urea nitrogen (SUN), insulin, T_3, and T_4. A quadratic effect of increasing dietary Lys was seen on ADG on d 28 showing that the addition of Lys increased gain ($P < 0.01$). Additionally, feed efficiency, energy intake, and Lys intake increased linearly as dietary Lys concentration increased from 0.40% to 0.56% AID Lys ($P < 0.01$). Levels of T_3 increased with increasing Lys ($P < 0.01$), but there was no effect of diet on SUN, T_4, or insulin. Ultrasound estimates of BF and LEA tended to increase linearly and quadratically, respectively, as dietary Lys increased ($P < 0.10$). Digestibility of energy, protein, NDF, and hemicellulose increased linearly in pigs fed 0.40–0.56% AID Lys ($P < 0.05$). These results demonstrate that formulating diets to meet the recommended AID Lys:ME is not sufficient to ensure optimal growth. Therefore, the concentration of protein and energy of the diet must be individually evaluated and corrected to obtain optimal growth and efficiency.

1. Introduction

The ability to feed alternative feedstuffs without negative effects on carcass composition and feed efficiency is essential for swine producers to maintain profitability. It is generally accepted that growing–finishing pigs will eat to meet their energy requirement, at least within a practical range of the nutrient density of the diet (Ellis and Augspurger, 2001). It is similarly assumed that dietary amino acids must be adjusted in the diet to change proportionally to dietary energy (Lewis, 2001). However, with the use of alternative feedstuffs that contain higher levels of fiber or fat or both, meeting the amino acid and energy requirements can be a challenge.

Previous studies have demonstrated that as the Lys:ME increases, pigs become more efficient and increase average daily gain (Chiba et al., 1991; De La Llata et al., 2007b; Main et al., 2008). In a review by Pettigrew and Moser (1991) it was shown that the addition of supplemental fat below 3% in the diet had no effect on carcass fat but, the addition of fat above 3% had an incremental increase in carcass fat in growing finishing pigs. There have been numerous studies investigating the effect of Lys:ME on performance of growing–finishing swine however, these studies adjust the Lys:ME as nutrients are added to the diet and all these studies were maintained above the NRC (1998) recommendations (Apple et al., 2004; De La Llata et al., 2007b; Main et al., 2008). There are no current studies on the effect of changing nutrient density of the diet while maintaining a constant Lys:ME. The importance of having an understanding of the ratio would be analogous to understanding the ideal pattern of amino acids. Once the ideal pattern (NRC, 1998, 2012) is known relative to Lys, determining the Lys requirement will then set all other essential amino acids in the diet. Similarly, since energy density of the diet determines intake,

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the Lys to energy ratio in the diet will determine Lys intake at a particular energy level. Therefore, the objective of this experiment was to determine if growth performance and digestibility of the feed consumed by barrows are effected by adjusting the energy and digestible Lys concentration of the diet, below and above NRC (1998) recommendations, while maintaining a constant AID Lys: ME.

2. Materials and methods

2.1. Animals and experimental design

Experimental protocols were approved by the University of Georgia Institutional Care and Use Committee. All nutrient levels met or exceeded NRC (1998) recommendations except for 0.40% AID Lys diet which was deficient in both Lys and Thr (0.40% vs NRC (1998) at 0.41%) and the 0.44% AID Lys which was deficient in Lys alone. Feed and water were available ad libitum for all pigs during the entire experiment.

The experiment was conducted in the Large Animal Research Unit at the University of Georgia in 2010 in two replicates of 25 individually housed barrows each (total 10 replicates per diet), using pigs from consecutive farrowing groups. Pigs (PIC 280 sire x C42 dams, PIC, Hendersonville, TN) had an initial body weight of 85.3 (+/−2.3) kg and were blocked by weight and randomly allotted to 1 of 5 dietary treatments. Pigs were housed in an environmentally controlled room with a 12-h light/dark cycle (light on from 0600 to 1800 h) in pens with a woven wire floor (1.83×4.27 m^2). The diets (Table 1) were formulated to contain total Lys of: (1) 0.50%, (2) 0.55%, (3) 0.60%, (4) 0.65%, and (5) 0.70% Lys, which corresponds to apparent ileal digestible (AID) values of 0.40, 0.44, 0.48, 0.52 and 0.56% Lys, respectively. All diets were formulated to meet a constant digestible Lys to ME ratio (AID Lys: ME) of 1.44 g AID Lys/Mcal ME while maintaining other essential amino acids in at least the ideal pattern (NRC, 1998). Lysine (and other amino acid levels) were changed by altering the corn to soybean meal amounts in the diet. No crystalline amino acids were used in this study. Dietary energy was reduced by the addition of fiber (Solka Floc; International Fiber Corporation, North Tonawanda, NY; added to the 0.40% and 0.44% Lys diets) and increased by the addition of fat (added to the 0.52% and 0.56% AID Lys diets). Titanium dioxide was added to the diet at 0.2% as a digestibility marker. All animals were placed on a 0.48% digestible Lys diet one week prior to the start of the experiment to normalize growth.

2.2. Measurements

Body weight, feed intake and ultrasound measures of fat thickness and loin eye area were measured on d 0, 14 and 28. On d 28, blood samples were drawn from each pig via jugular vein puncture and placed on ice. Pigs were not fasted prior to collecting blood. The blood was centrifuged ($1200 \times g$ at 4 °C for 20 min) and blood serum was extracted and frozen at −20 °C for later analysis. Blood serum samples were used to analyze serum urea nitrogen (SUN), insulin, T_3, and T_4. A commercial kit was used to measure end point SUN concentration indirectly by coupled enzyme reactions involving urease and glutamate dehydrogenase (Sigma BUN End point assay; Sigma Diagnostics, Inc., St. Louis, MO). Total serum insulin, T_3, and T_4 were determined by RIA using commercially available kits (ICN Biochemicals, Costa Mesa, CA).

Crude protein (N) content of the diet was analyzed using a N analyzer (LECO FP-528; LECO Corp., St. Joseph, MI). A bomb calorimeter was used to determine gross energy of the diets (Parr Model 1261; Parr Instrument Co., Moline, IL). Dietary crude fat was determined following the AOAC (2008) official procedure (920.39) for ether extraction (Labconco Goldfisch Fat Extractor; Labconco, Kansas City, MO). Fecal samples were collected from individual pigs during weighing on d 21 and 28 and combined. Samples were oven dried at 49 °C, finely ground, and placed in −80 °C freezer until analysis. Titanium in the diet and feces was determined as described by Titgemeyer et al. (2001). Ultrasound sound images of back fat thickness and loin area at the 10th rib were collected and interpreted using swine image analysis software (Designer Genes Technologies, Inc, Harrison, AR.).

Table 1
Composition and analysis of diets (as-fed basis)[a].

Digestible Lys (%):	0.40	0.44	0.48	0.52	0.56
Metabolizable Energy (Mcal/kg):	2.78	3.05	3.33	3.66	3.86
Ingredients (%)					
Corn	70.66	77.73	84.79	76.82	68.83
Soybean meal 48% CP	10.59	11.65	12.74	15.11	17.51
Poultry fat	0.00	0.00	0.00	5.60	11.20
Fiber source[b]	16.21	8.11	0.00	0.00	0.00
Limestone	0.87	0.89	0.89	0.89	0.87
Dicalium phosphate	0.82	0.77	0.73	0.73	0.74
Common salt	0.35	0.35	0.35	0.35	0.35
Vitamin premix[c]	0.15	0.15	0.15	0.15	0.15
Mineral premix[d]	0.15	0.15	0.15	0.15	0.15
Titanium oxide	0.20	0.20	0.20	0.20	0.20
Calculated analysis[e]					
Crude protein (%)	11.33	12.56	13.68	14.14	14.59
Metabolizable Energy (Mcal/kg)	2.78	3.05	3.33	3.60	3.86
Ether extract (%)	2.79	3.07	3.35	8.67	14.00
Lys (%)	0.50	0.55	0.60	0.65	0.70
Met+Cys (%)	0.40	0.44	0.48	0.49	0.49
Thr (%)	0.40	0.45	0.49	0.51	0.53
Trp (%)	0.12	0.13	0.15	0.16	0.17
Total Lys: ME (g/Mcal)	1.83	1.83	1.83	1.83	1.83
Digestible Lys: ME	1.44	1.44	1.44	1.44	1.44
Chemical analysis					
Crude protein (%)	11.48	12.47	14.18	14.89	15.78
Lys (%)	0.48	0.54	0.57	0.59	0.70
Met+Cys (%)	0.37	0.39	0.44	0.45	0.48
Thr (%)	0.40	0.44	0.47	0.49	0.53
Trp (%)	0.12	0.13	0.15	0.15	0.15
Ether extract (%)	2.25	2.13	2.78	7.43	12.93
NDF (%)	24.44	17.83	11.61	13.33	13.36
ADF (%)	13.20	8.50	3.00	2.70	2.90

[a] Increasing Lys while maintain Ly:ME were accomplished by replacing corn with soybean meal and adding Solka Floc for filler or poultry fat for energy.
[b] Solka Floc(SF40FCC, purified cellulose), International Fiber Corporation, North Tonawanda, NY.
[c] The vitamin premix (Animal Science Products, Nacogdoches, TX) provided the following per kilogram of complete diet: 11,000 IU vitamin A, 1650 IU vitamin D_3, 44 IU vitamin E, 4.4 mg vitamin K, 9.9 mg riboflavin, 55 mg niacin, 33 mg pantothenic acid, 44 μg vitamin B_{12}.
[d] The trace mineral premix (Animal Science Products, Nacogdoches, TX) provided the following per kilogram of complete diet: 165 mg Fe ($FeSO_4 \cdot H_2O$), 16.5 mg Cu ($CuSO_4 \cdot 5H_2O$), 39.6 mg Mn ($MnSO_4$), 165 mg Zn (ZnO), 0.3 mg I ($Ca(IO_3)_2$), and 0.3 mg Se (Na_2SeO_3).
[e] Calculated values from NRC (1998) were used in diet formulation.

2.3. Statistical analysis

All statistics were performed using General Linear Models procedure of SAS (SAS Institute, Inc., Cary, NC). The experiment was a randomized complete block design with 5 treatments. The experimental unit was the pig. Least squares means, probabilities of differences and standard errors of the means were obtained. Planned orthogonal contrasts were completed to determine linear and quadratic effects of inclusion of Lys in the diet. Differences were considered significant at $P < 0.05$ and was assumed a trend at $P < 0.10$.