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The Effect of Dietary Lysine on Growth, Carcass Composition, and Lipid Metabolism in High-Lean Growth Gilts Fed from 72 to 136 Kilograms[1,2]

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ABSTRACT: One hundred fourteen high-lean growth gilts (72.5 kg BW) were used to determine the apparent digestible lysine requirement for maximum growth performance and carcass protein deposition rate from 72.5 to 136 kg BW. The experiment was a randomized complete block design with initial BW used to establish blocks. Six dietary treatments were included, ranging from .44 to .94% (.10% increments) apparent digestible lysine (.62 to 1.13% total lysine) with six replicate pens per treatment and three pigs per pen. Pig weights and feed consumption were collected weekly to determine ADG, ADFI, and gain: feed ratio (G/F). Six gilts were slaughtered at 72.5 kg BW to determine initial carcass composition. When the mean weight of pigs in a pen reached 104 or 136 kg, one pig per pen was selected (closest to 104 or 136 kg, respectively) and slaughtered for determination of carcass measurements and composition. From 72.5 to 104 kg and from 104 to 136 kg, ADG and G/F increased (linear, $P < .05$; quadratic, $P < .10$, respectively) as apparent digestible lysine increased. From 72.5 to 136 kg, G/F increased (quadratic, $P < .10$) as apparent digestible lysine increased. Average backfat thickness and longissimus muscle area at 104 kg were not influenced ($P > .10$) by apparent digestible lysine. However, average backfat thickness increased (quadratic, $P < .05$) with increasing digestible lysine for gilts slaughtered at 136 kg. Carcass CP accretion was not influenced ($P > .10$) from 72.5 to 104 kg but tended to increase (linear, $P < .10$) from 72.5 to 136 kg as digestible lysine increased. Plasma and longissimus muscle cholesterol concentrations were unaffected ($P > .10$) by increasing digestible lysine. These results suggest that high-lean growth gilts require greater dietary lysine than current NRC (1988) estimates to maximize ADG, G/F, and carcass CP accretion from 72.5 to 104 and from 104 to 136 kg.

Key Words: Pigs, Growth, Carcass Composition, Genotype, Gilts

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Introduction

In order to develop effective feeding strategies for individual groups of growing-finishing pigs, it is important that the pig's lean growth potential be considered. For example, Stahly et al. (1988) suggested that dietary lysine requirements are 2 to 4 g/d greater for high-lean growth barrows than for medium-lean growth barrows fed from 22 to 109 kg. Growth models developed by Whittemore et al. (1988) indicate that protein deposition is maximized between body weights of 55 to 72 kg, depending on the genotype and sufficient intake. Therefore, it would seem imperative that amino acid requirements be established based on the rate of protein (lean) deposition. Recently, Friesen et al. (1994a,b) observed that high-lean growth gilts fed from 34 to 72.5 kg require 16 to 59% higher dietary lysine than NRC (1988) estimates to support the greater rate of protein gain. These data are in agreement with Campbell et al. (1988), who suggested greater digestible lysine for high-lean growth gilts fed to 90 kg. Thus, our objective was to determine the lysine requirement for maximum growth rate, feed efficiency, and protein deposition in high-lean growth gilts (72 kg initial

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Table 1. Diet composition (as-fed basis)

	Digestible lysine, %					
Item, %	.44	.54	.64	.74	.84	.94
Corn	82.75	78.83	74.90	70.92	66.93	62.92
Soybean meal (48.5% CP)	10.88	14.89	18.90	22.91	26.93	30.94
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
L-Lysine·HCl	.05	.05	.05	.05	.05	.05
L-Threonine	—	—	.008	.03	.052	.083
DL-Methionine	—	—	.002	.036	.072	.12
Monocalcium phosphate (21% P)	1.66	1.58	1.51	1.44	1.37	1.30
Limestone	.96	.95	.93	.92	.90	.89
Salt	.35	.35	.35	.35	.35	.35
Trace mineral premix[a]	.15	.15	.15	.15	.15	.15
Vitamin premix[b]	.20	.20	.20	.20	.20	.20

[a]Provided the following per kilogram of complete diet: Mn, 100 mg; Fe, 100 mg; Zn, 100 mg; Cu, 10 mg; I, 3 mg; Co, 1 mg; Se, .3 mg.
[b]Provided the following per kilogram of complete diet: vitamin A, 3,306 IU; vitamin D_3, 331 IU; vitamin E, 13 IU; riboflavin, 3.3 mg; d-pantothenic acid, 8.3 mg; niacin, 18.2 mg; choline, 331 g; vitamin B_{12}, .02 mg; menadione (menadione sodium bisulfate complex), 1.3 mg.

BW) fed throughout the finishing period to market weights of 104 or 136 kg. Because dietary lysine affects carcass lipid deposition, additional response criteria included longissimus lipid and cholesterol content and plasma cholesterol and triglyceride concentrations.

Materials and Methods

Animals. A growth assay was conducted using 114 high-lean growth gilts (initially 72.5 kg BW) to evaluate the dietary lysine requirement for maximal growth and carcass protein deposition. Genetic potential for lean tissue deposition was predetermined for this population (Pig Improvement Co., L326, Franklin, KY). Gilts from the same population and used in a previous experiment (Friesen et al., 1994a) exhibited lean deposition rates between .41 and .47 kg/d from 35 to 72.5 kg. Stahly (1991) suggested that high-lean growth pigs should have a lean tissue deposition rate exceeding .34 kg/d. The gilts (32 kg) were delivered to the Kansas State University Swine Teaching and Research Center and were housed (4.6-m × 1.2-m pens with solid flooring) in an open-fronted building, with three gilts per pen. Gilts were fed a corn-soybean meal diet formulated to provide 1.15% total lysine until they reached approximately 72.5 kg BW. At this time, gilts were reassigned on the basis of weight to pens with six replications (pens) per treatment. The trial was conducted from March to July 1993. When temperatures exceeded 29°C, drip coolers were activated to wet the pigs for 3 out of every 15 min. Each pen contained a single-hole feeder and a nipple waterer to accommodate ad libitum access to feed and water. Pig weights and feed consumption were recorded weekly to determine ADG, ADFI, gain: feed ratio (**G/F**), and dietary lysine intake.

Diet Formulation. Dietary treatments ranged from .44 to .94% apparent digestible lysine (Table 1); total analyzed dietary lysine ranged from .62 to 1.13%. Other dietary amino acid levels (on an apparent digestibility basis) were set using an ideal amino acid ratio (Chung and Baker, 1992) to ensure that lysine was the first-limiting amino acid. Calculated amino acid digestibility coefficients (Knabe et al., 1989) were used for the feed ingredients. The apparent lysine ileal digestibility coefficients for corn, soybean meal, and feed grade L-lysine·HCl were 64, 85, and 93%, respectively. The corn:soybean meal ratio was altered to increase the dietary lysine content. L-lysine·HCl inclusion was maintained at .05% of the complete diet, so that lysine bioavailability would not be influenced by high inclusion of synthetic amino acids (Batterham and O'Neill, 1978). The dietary ME was increased in all diets to 3,416 kcal/kg by the addition of soybean oil, so that the lysine:ME ratio ranged from 1.97 to 3.31 g/Mcal. All other nutrients either met or exceeded NRC (1988) estimates for the 50- to 100-kg pig. Chemical composition (CP, lipid, moisture, and ash) of the diets was determined by AOAC (1990) procedures. Amino acid analysis of diets (Knabe et al., 1989) was determined by ion exchange chromatography following acid hydrolysis (Table 2). Cystine and methionine were determined following oxidation with performic acid (Moore, 1963). Tryptophan was determined by alkaline hydrolysis (LaRue, 1985).

Plasma Cholesterol and Triglyceride. Blood samples were collected in heparinized tubes on d 14, 28, 42, and 56 via vena cava puncture. Feeders were removed from each pen at approximately 0800 and blood samples were collected from all pigs 3 h later. Samples were centrifuged at 2,000 × *g* for 30 min within 1 h of collection. Within 48 h of collection, the low-density lipoprotein (**LDL**) was separated from the high-density lipoprotein (**HDL**) fraction using column separation kits (IsoLab, Akron, OH). Total, LDL, and HDL cholesterol and triglyceride content then were determined enzymatically (Sigma Diagnostics, St.

Table 2. Chemical analysis of experimental diets[a]

Item, %	Digestible lysine, %					
	.44	.54	.64	.74	.84	.94
CP (N × 6.25)	11.39	13.21	15.14	16.07	17.43	18.96
Arginine	.77	.88	1.05	1.19	1.14	1.26
Cystine	.29	.31	.33	.35	.33	.37
Glycine	.52	.58	.66	.72	.71	.80
Histidine	.38	.41	.46	.51	.49	.53
Isoleucine	.54	.58	.69	.74	.75	.83
Leucine	1.39	1.50	1.59	1.71	1.66	1.78
Lysine	.62	.73	.87	1.05	1.07	1.13
Methionine	.24	.25	.28	.33	.36	.44
Phenylalanine	.66	.73	.82	.92	.89	.98
Serine	.56	.67	.72	.78	.77	.88
Threonine	.46	.54	.60	.68	.69	.81
Tryptophan	.11	.13	.18	.20	.20	.23
Tyrosine	.43	.49	.55	.62	.60	.66
Valine	.64	.68	.79	.84	.84	.91
Ca[b]	.75	.75	.75	.75	.75	.75
P[b]	.65	.65	.65	.65	.65	.65
ME, kcal/kg[b]	3,416	3,416	3,416	3,416	3,416	3,416

[a]Analyzed values expressed on an as-fed basis.
[b]Calculated values expressed on an as-fed basis.

Louis, MO) for samples collected on d 14, 28, 42 and 56. The samples collected on 0 d were analyzed for total cholesterol and triglyceride only. Cholesterol and triglyceride standards were obtained from Sigma to determine the standard curve.

Carcass Characteristics. Procedures for carcass evaluation were described previously by Friesen et al. (1994a). When the mean weight of pigs in a pen reached 104 or 136 kg, one pig in each pen (closest to 104 or 136 kg, respectively) was killed. Carcass weights were taken immediately after slaughter and at 24 h postmortem. Dressing percentage was determined from live weight and hot carcass weight. The heart, liver, kidneys, and kidney fat were removed from each carcass and weighed. Backfat thickness was measured at the first rib, last rib, and last lumbar vertebrae from both the right and left side of the carcass. Longissimus muscle area and fat depth were recorded at the 10th rib.

Carcass Composition. Initial composition was determined from six gilts slaughtered at 72.5 kg, and endpoint composition was determined at 104 and 136 kg. The head, leaf fat, and viscera were removed at slaughter and were not included in determining carcass accretion rate. At 24 h postmortem, the right side of each carcass was ground once through a 15-mm plate, once through a 9-mm plate, and homogenized for 3 min in a ribbon-paddle mixer. Chemical composition was determined by AOAC (1990) procedures. Mean initial carcass content of the six gilts, determined from chemical composition at 72.5 kg BW, was subtracted from carcass chemical content measured at either 104 or 136 kg. Tissue accretion rates were calculated as this difference divided by the days on test.

Longissimus Muscle Lipid Content. Longissimus muscle samples (2.54-cm chops) were taken between the 10th and 11th rib at 24 h postmortem, vacuum-packaged, and frozen at –20°C. The samples were pulverized in a Waring Blender (Waring Product Division, New Hartford, CT) with liquid nitrogen. Lipid extraction was conducted using a modified version of the procedure of Folch and Sloane Stanley (1957). Briefly, 1 g of tissue was mixed and incubated with 50 mL of chloroform-methanol (2:1 ratio) for 24 h. The solution was filtered (Whatman #1; Whatman Lab Sales, Maidstone, U.K.) and the filtrate was collected. Ten milliliters of NaCl solution (.73% vol/wt) was added to the filtrate, and the resulting volume was brought to 50 mL with chloroform-methanol. After separation for 24 h, the aqueous layer was removed by aspiration, and the lower layer was dried under nitrogen. The dried sample was then weighed to give the tissue lipid content. The lipid extract was analyzed for cholesterol as described by Rudel and Morris (1973).

Statistical Analysis. Data were analyzed as a randomized complete block design using initial BW to establish blocks. The GLM procedure of SAS (1988) was used to analyze the data. The pen of pigs was used as the experimental unit. Treatment means were separated using linear and quadratic polynomials (Peterson, 1985). Similarly, carcass data at 104 and 136 kg live weight were analyzed using the linear and quadratic polynomials; however, live weight at slaughter was included as a covariate. Carcass tissue accretion rates from 72.5 to 104 and from 72.5 to 136 kg were analyzed initially using live weight at the slaughter points (104 and 136 kg) as a covariate. However, the covariate was not significant ($P = .35$),

so unadjusted data were used for the analysis. Plasma cholesterol and triglyceride data were evaluated by least squares analysis of variance for repeated measures in a split-plot design (Gill and Hafs, 1971). Pen was defined as the experimental unit (mean of two or three samples per pen) with treatment as the main plot and sampling day as the repeated measure (subplot). The main plot was tested using pen within treatment × block mean square as the error term. The subplot effects of sampling day and treatment × sampling day were tested by the residual mean square. Inflection point analysis was used to determine the optimal digestible lysine concentration for ADG and G/F from 104 to 136 kg and G/F from 72.5 to 136 kg. The data were fit to a quadratic model (Walker and Carmer, 1967). This provides for a 95% lower confidence bound, which ensures that the optimal dose exceeds the lower bound. The inflection point (optimal dose) analysis is based on an analysis of variance for all the response data and thus the average pig in the population is of concern for all analyses.

Results

Growth Performance. Increasing digestible lysine resulted in greater ADG (Table 3) from 72.5 to 104 kg (linear, $P < .01$). From 104 to 136 kg, ADG increased with digestible lysine up to .74% and then decreased (quadratic, $P < .10$). However, from 72.5 to 136 kg, ADG was not influenced ($P > .10$) by digestible lysine. The inflection point (quadratic model) projected maximum ADG at .71% digestible lysine from 104 to 136 kg. Average daily feed intake was not influenced ($P > .10$) by digestible lysine from 72.5 to 104, 104 to 136, or 72.5 to 136 kg. Thus, increased ADG at similar ADFI resulted in improved G/F from 72.5 to 104 kg (linear, $P < .05$). From 104 to 136 kg (quadratic, $P < .10$) and from 72.5 to 136 kg (quadratic, $P < .10$) G/F was highest for pigs fed .74% digestible lysine. Inflection point analyses indicated maximum G/F at .73% apparent digestible lysine from 104 to 136 kg and from 72.5 to 136 kg. Total lysine intake was greater (linear, $P < .01$) for all three weight periods as digestible lysine increased from .44 to .94%.

Carcass Characteristics. Gilts slaughtered at 104 kg had similar ($P > .10$) live weights as well as hot and chilled carcass weights regardless of digestible lysine level (Table 4). Thus, dressing percentages were similar ($P > .10$) among pigs fed the various digestible lysine levels. Average backfat thickness (2.2 to 2.3 cm) and 10th rib fat depth (1.6 to 1.9 cm) were similar ($P > .10$) for all gilts regardless of digestible lysine. Longissimus muscle area ranged from 36.1 to 38.1 cm^2 and was not influenced ($P > .10$) by digestible lysine. Digestible lysine did not influence ($P > .10$) either the carcass length or the kidney fat weight. Carcass moisture, CP, and lipid concentrations were similar ($P > .10$) regardless of digestible lysine treatment. Carcasses contained on average 62.7% moisture, 16.5% CP, and 17.8% lipid. However, ash content was decreased (linear, $P < .03$) as digestible lysine increased. Heart and kidney weight expressed as a percentage of BW were not influenced ($P > .10$) by digestible lysine. Liver weight increased

Table 3. Effect of increased digestible lysine on growth performance of high-lean growth gilts[a]

	Digestible lysine, %						
Item	.44	.54	.64	.74	.84	.94	CV
ADG, kg							
72.5 to 104 kg[b]	.84	.88	.88	.89	.82	.93	7.17
104 to 136 kg[c]	.85	.80	.83	.98	.92	.77	14.19
72.5 to 136 kg	.84	.84	.86	.92	.91	.85	7.05
ADFI, kg							
72.5 to 104 kg	2.97	2.83	2.93	2.92	3.03	2.94	7.74
104 to 136 kg	3.03	2.87	3.15	2.89	3.07	3.09	10.34
72.5 to 136 kg	2.99	2.84	3.01	2.93	3.05	3.01	7.48
G/F							
72.5 to 104 kg[d]	.28	.31	.30	.31	.31	.32	7.54
104 to 136 kg[c]	.28	.28	.26	.35	.30	.25	14.40
72.5 to 136 kg[c]	.28	.30	.29	.31	.30	.28	7.04
Total lysine intake, g/d							
72.5 to 104 kg[b]	16.3	19.0	23.1	26.6	31.2	33.9	9.1
104 to 136 kg[b]	16.7	19.2	24.9	26.3	31.6	35.5	11.2
72.5 to 136 kg[b]	16.4	19.1	23.8	26.7	31.4	34.6	8.5

[a]A total of 108 pigs, three pigs per pen from 72.5 to 104 kg and two pigs per pen from 104 to 136 kg; six replicate pens per treatment.
[b]Linear effect of digestible lysine ($P < .01$).
[c]Quadratic effect of digestible lysine ($P < .10$).
[d]Linear effect of digestible lysine ($P < .05$).

Table 4. The effect of increased digestible lysine on carcass characteristics and composition in high-lean growth gilts slaughtered at 104 kg[a]

	Digestible lysine, %						
Item	.44	.54	.64	.74	.84	.94	CV
Live wt, kg	103.9	103.9	103.4	104.4	103.9	105.7	2.6
Hot carcass wt, kg	74.9	73.7	73.9	75.0	74.2	75.2	4.1
Chilled carcass wt, kg	73.4	72.6	72.9	73.7	73.3	73.6	3.9
Dressing percentage	74.8	71.7	74.0	74.3	74.5	74.7	2.1
Average backfat thickness, cm	2.2	2.2	2.3	2.3	2.2	2.3	11.6
Tenth rib fat depth, cm	1.6	1.9	1.9	1.8	1.8	1.9	22.9
Longissimus muscle area, cm^2	36.1	37.4	36.8	38.1	37.4	37.4	11.5
Carcass length, cm	78.2	77.5	78.2	77.7	77.7	77.5	2.8
Kidney fat, kg	.9	1.1	.9	1.0	1.0	1.0	26.4
Carcass composition, %							
Moisture	61.7	62.8	64.5	61.8	63.2	62.1	4.1
CP (N × 6.25)	16.1	16.8	16.6	16.6	16.3	16.6	6.4
Lipid	18.9	17.4	16.0	18.5	17.5	18.5	14.6
Ash[b]	3.3	3.1	2.9	3.1	3.0	2.8	10.9
Organs, % of BW							
Heart	.48	.52	.77	.50	.51	.51	54.44
Liver[c]	1.82	1.97	2.01	2.07	1.99	2.24	10.21
Kidney	.47	.53	.45	.48	.52	.52	11.39

[a]Calculated from 36 pigs at a pen mean weight of 104 kg, one pig per pen, six pigs per treatment.
[b]Linear effect of digestible lysine ($P < .03$).
[c]Linear effect of digestible lysine ($P < .01$).

(linear, $P < .01$) in gilts as digestible lysine level in the diet increased.

At 136 kg live weight, hot and chilled carcass weights and dressing percentage were not influenced ($P > .10$) by digestible lysine (Table 5). Backfat thickness increased then decreased as digestible lysine increased (quadratic, $P < .05$). Tenth rib fat depth and longissimus muscle area were not influenced ($P > .10$) by digestible lysine. However, longissimus muscle area was numerically greatest for gilts fed .54%

Table 5. The effect of increased digestible lysine on carcass characteristics and composition in high-lean growth gilts slaughtered at 136 kg[a]

	Digestible lysine, %						
Item	.44	.54	.64	.74	.84	.94	CV
Live wt, kg	132.6	134.3	132.3	134.5	136.1	133.3	2.4
Hot carcass wt, kg	102.3	102.4	104.3	101.4	100.6	100.4	3.4
Chilled carcass wt, kg	100.6	100.6	102.5	99.9	99.1	98.7	3.4
Dressing percentage	76.4	76.5	75.8	75.3	74.7	75.8	2.1
Backfat thickness, cm[b]	2.8	2.8	3.0	2.8	3.0	2.5	12.8
Tenth rib fat depth, cm	2.5	2.8	2.8	2.5	3.0	2.4	22.9
Longissimus muscle area, cm^2	41.3	46.5	42.6	43.2	43.2	40.6	11.8
Carcass length, cm	85.3	83.8	85.3	84.8	84.6	86.6	2.3
Kidney fat, kg	1.9	2.3	2.3	2.0	2.1	2.1	28.2
Carcass composition, %							
Moisture	65.9	62.3	62.4	62.6	64.1	62.4	5.0
CP (N × 6.25)	15.1	14.8	14.4	15.1	15.6	15.9	8.6
Lipid	16.8	20.1	20.8	19.5	17.4	18.8	17.0
Ash[c]	2.5	2.8	2.5	2.8	2.7	3.1	13.7
Organs, % of BW							
Heart[d]	.41	.42	.43	.42	.46	.44	10.89
Liver[e]	1.60	1.62	1.71	1.85	1.88	1.78	11.28
Kidney[e]	.38	.39	.45	.42	.46	.45	7.71

[a]Calculated from 36 pigs at a pen mean weight of 136 kg, one pig per pen, six pigs per treatment.
[b]Quadratic effect of digestible lysine ($P < .05$).
[c]Linear effect of digestible lysine ($P < .05$).
[d]Linear effect of digestible lysine ($P < .10$).
[e]Linear effect of digestible lysine ($P < .01$).

Table 6. Effect of increased digestible lysine on longissimus muscle lipid and cholesterol content for high-lean growth gilts slaughtered at 104 and 136 kg[a]

	Digestible lysine, %						
Item, mg/g	.44	.54	.64	.74	.84	.94	CV
104 kg							
Lipid[b]	107	119	148	111	173	145	33.03
Cholesterol	1.43	1.21	1.44	1.65	1.69	1.67	44.75
136 kg							
Lipid	161	149	208	146	141	179	42.17
Cholesterol	1.52	1.47	1.91	1.42	1.51	1.54	37.29

[a]Means calculated from one pig per pen, six pigs per treatment.
[b]Linear effect of digestible lysine ($P < .05$).

digestible lysine. Digestible lysine content did not influence ($P > .10$) either carcass length or kidney fat content. Carcass moisture, CP, and lipid were not affected ($P > .10$) by digestible lysine when gilts weighed 136 kg. On average, each carcass contained 63.3% moisture, 15.2% CP, and 18.9% lipid. Ash content increased (linear, $P < .05$) as digestible lysine increased. Increased digestible lysine resulted in greater percentages of heart (linear, $P < .10$), liver (linear, $P < .01$), and kidney (linear, $P < .01$) relative to live weight.

Longissimus Muscle Lipid Content. Longissimus muscle lipid content at 104 kg was greater (linear, $P < .05$), whereas cholesterol content was not influenced ($P > .10$) as digestible lysine increased from .44 to .94% (Table 6). At 136 kg, neither longissimus muscle lipid nor cholesterol was influenced ($P > .10$) by digestible lysine.

Tissue Accretion Rates. From 72.5 to 104 kg, moisture, CP, and lipid accretion were not influenced ($P > .10$) by digestible lysine (Table 7). Ash accretion was reduced (linear, $P < .05$) as digestible lysine increased from .44 to .94%. From 72.5 to 136 kg, moisture accretion was not influenced ($P > .10$) by digestible lysine ranging from .44 to .94%. Increased digestible lysine resulted in greater CP accretion (linear, $P < .10$). Lipid and ash accretion were not influenced ($P > .10$) as digestible lysine increased from .44 to .94%.

Plasma Cholesterol and Triglyceride. There were no treatment × sampling day interactions ($P > .10$) observed for plasma cholesterol or triglyceride concentrations. Initially (d 0), plasma cholesterol concentration were similar ($P > .10$) regardless of digestible lysine treatment (Table 8). However, the basal triglyceride level increased then decreased (quadratic, $P < .05$) in gilts as digestible lysine level increased. At d 14, total plasma cholesterol decreased and then increased (quadratic, $P < .05$) as digestible lysine increased from .44 to .94%. This reduction was accounted for by the similar decrease and increase (quadratic, $P < .01$) in HDL and LDL cholesterol ($P > .10$) as digestible lysine increased. The HDL:LDL ratio decreased (linear, $P < .01$) and triglyceride content remained constant at d 14. By d 28, no difference was found ($P > .10$) in total plasma cholesterol content. However, HDL cholesterol decreased (linear, $P < .01$) whereas LDL cholesterol was not influenced ($P > .10$) for gilts fed increased digestible lysine. This reduction in HDL cholesterol

Table 7. Effect of digestible lysine on carcass tissue accretion rates in high-lean growth gilts fed from 72.5 to 104 or 136 kg[a]

	Digestible lysine, %						
Item, g/d	.44	.54	.64	.74	.84	.94	CV
72.5 to 104 kg							
Moisture	309	279	326	317	294	320	17
CP	92	95	102	105	102	106	17
Lipid	167	132	115	153	154	163	33
Ash[b]	24	19	18	20	17	15	32
72.5 to 136 kg							
Moisture	310	297	330	321	315	307	16
CP[c]	86	87	92	92	99	103	22
Lipid	153	172	193	167	143	164	31
Ash	15	18	15	18	15	21	36

[a]Calculated from 36 pigs each at a pen mean weight of 104 and 136 kg, one pig per pen, six pens per treatment.
[b]Linear effect of digestible lysine ($P < .05$).
[c]Linear effect of digestible lysine ($P < .10$).

Table 8. Effect of dietary lysine on plasma cholesterol, HDL, LDL, HDL:LDL ratio, and triglyceride concentrations in high lean-growth gilts fed from 72.5 to 136 kg[a]

	Digestible lysine, %						
Item, mg/dL	.44	.54	.64	.74	.84	.94	CV
Day 0							
Total cholesterol	79.91	80.22	82.71	80.71	72.49	81.62	9.57
Triglyceride[b]	26.09	26.96	30.79	27.94	25.96	24.70	15.64
Day 14							
Total cholesterol[b]	86.18	80.61	79.51	75.85	78.35	82.17	10.34
HDL[cd]	36.63	31.31	32.81	29.19	28.96	31.23	9.51
LDL	47.97	44.90	47.23	45.02	45.95	49.44	11.46
HDL:LDL[c]	.77	.70	.70	.66	.64	.63	10.99
Triglyceride	28.25	23.76	27.60	25.30	27.88	23.69	19.82
Day 28							
Total cholesterol	88.63	86.98	92.83	80.82	80.72	83.57	13.72
HDL[c]	39.65	36.41	37.06	33.73	31.41	33.95	14.35
LDL	48.56	48.18	51.33	45.97	46.44	49.51	17.24
HDL:LDL[e]	.82	.75	.74	.76	.69	.69	15.26
Triglyceride[c]	29.58	28.49	28.50	25.34	24.10	26.22	10.74
Day 42							
Total cholesterol	85.04	80.68	85.67	81.37	78.14	78.38	9.86
HDL[f]	37.07	34.48	36.24	34.20	33.17	33.09	11.57
LDL	46.21	44.20	46.64	45.38	42.39	45.38	13.65
HDL:LDL	.82	.79	.79	.76	.79	.73	14.11
Triglyceride	26.71	26.62	27.94	26.93	20.92	25.92	20.31
Day 56							
Total cholesterol	78.10	79.30	86.01	73.92	72.70	78.43	7.45
HDL	32.66	35.54	34.68	31.90	30.82	32.28	9.88
LDL	43.02	41.24	49.77	39.53	37.51	43.31	14.16
HDL:LDL	.77	.87	.74	.81	.84	.75	15.36
Triglyceride	29.79	24.37	33.97	25.19	28.92	33.00	22.38

[a]Means calculated from three pigs per pen (72 to 104 kg) and two pigs per pen (104 to 136 kg), six pens per treatment.
[b]Quadratic effect of digestible lysine ($P < .05$).
[c]Linear effect of digestible lysine ($P < .01$).
[d]Quadratic effect of digestible lysine ($P < .01$).
[e]Linear effect of digestible lysine ($P < .05$).
[f]Linear effect of digestible lysine ($P < .10$).

resulted in a reduced (linear, $P < .05$) HDL:LDL ratio. Plasma triglyceride content was decreased (linear, $P < .01$) as digestible lysine increased to .94%. On d 42 of the experiment, total and LDL cholesterol contents were not affected by digestible lysine. High-density lipoprotein cholesterol tended to decrease (linear, $P < .10$) as digestible lysine increased. Repeated measures analysis indicated cholesterol concentrations were highest on d 28 ($P < .05$) compared with values observed on other sampling days. Concentrations of HDL and LDL seemed to increase then decrease ($P < .05$); however, the ratio of HDL:LDL increased on each sampling day ($P < .05$). Plasma triglyceride content was not affected ($P > .10$) by digestible lysine, nor was it affected by sampling day ($P > .10$). Total, HDL, and LDL cholesterol; HDL:LDL ratio; and plasma triglyceride contents were not affected ($P > .10$) by digestible lysine on d 56 of the experiment.

Discussion

Unlike our previous study with 34- to 72-kg gilts (Friesen et al., 1994b), growth performance was not dramatically influenced by dietary lysine. Although ADG and G/F from 72.5 to 104 kg were improved linearly ($P < .01$ and $P < .05$, respectively), the relative magnitude of improvement was small and seems to be biased by performance of pigs fed .94% digestible lysine. From 104 to 136 kg, inflection point analysis projected maximum ADG and G/F at .71 and .74% digestible lysine, respectively. Cumulative results (72 to 136 kg) suggest no response in ADG to digestible lysine; however, G/F was maximized at .71% digestible lysine (inflection point). Therefore, these data suggest lysine estimates change at different rates for gain and efficiency of gain as the gilt becomes heavier. However, based on the response in G/F to digestible lysine, data from this experiment suggest a requirement of 21 g/d digestible lysine intake. This estimate is greater than current NRC (1988) standards (25 vs 19 g/d total lysine intake). Cromwell et al. (1993) estimated 25 g/d of lysine intake (.90% total lysine) for gilts fed from 51 to 105 kg BW. Results of Stahly et al. (1988) and Stahly (1991) indicated that high-lean growth barrows

require between 23 and 27 g/d of lysine intake (.80 to .95% total lysine) from 22 to 109 kg. However, this does not take into account the changes in lysine needs at different points in the growth curve. Initially (22 kg), the pigs are in the accelerating portion of the growth curve, followed by the inflection point, and finally a decreasing rate of growth (Whittemore et al., 1988). Our data estimate requirements for gilts near the inflection point of the growth curve and beyond. Estimations of amino acid needs for finishing pigs heavier than 110 kg have not been studied extensively, nor has the efficiency of amino acid use for maintenance and growth for pigs fed to heavier weights. Previous results from our laboratory (Friesen et al., 1994b) indicated that the magnitude of response to greater dietary lysine was diminished as BW increased above 100 kg. These data are in accordance with the results of Carr et al. (1978), which suggested that the rate and efficiency of weight gain decreased as BW increased from 68 to 138 kg. Shields et al. (1983) also suggested poorer performance as BW increased above 100 kg. Furthermore, the composition of gain was shifted toward greater lipid deposition rather than carcass CP accretion.

In the present study, carcass protein was not influenced by digestible lysine, and the total percentage of carcass protein decreased by nearly 2 to 3.5% as a result of increased BW from 72.5 to 136 kg. Previously, greater carcass CP content and accretion resulted for high-lean growth gilts (34 to 72.5 kg) fed .94% digestible lysine than for gilts fed .54% digestible lysine (Friesen et al., 1994a). In comparison with our previous results, the carcass CP accretion rates in this experiment suggest that protein gain is higher for gilts of less than 72.5 kg BW. A reduction in carcass CP content is consistent with the results of Shields et al. (1983), who suggested an approximately 4% decrease in carcass CP content as BW increased from 36 to 145 kg.

Results of Campbell et al. (1984), Rao and McCracken (1990), and Yen et al. (1986) suggested increases in protein deposition for high-lean growth boars and gilts when fed 22 to 26 g/d lysine. Our data indicated moderate improvements in CP accretion by increasing digestible lysine from .44 to .94%. These improvements in CP accretion were not different ($P >$ .10) from 72.5 to 104 kg (14 g/d), and only a tendency was observed from 72.5 to 136 kg (linear, $P < .10$). The rate of CP accretion was nearly 30 to 40 g/d less in finishing gilts (72.5 to 136 kg) than in growing gilts (34 to 72.5 kg; Friesen et al., 1994a). These differences in carcass CP accretion may potentially be related to the small response to digestible lysine in high-impetus muscles (i.e., longissimus muscle) as BW increases. Davies (1974) suggested high-impetus muscles mature at BW less than 104 kg. Therefore, little to no response to digestible lysine at greater than 104 kg BW may reflect a plateau in this genotype's growth curve.

Whittemore et al. (1988) suggested that the potential for protein deposition and actual protein deposition are limited by feed intake in growing pigs. As the pig matures, the actual deposition rate and the potential are similar, because of increased ADFI. At heavier BW (104 and 136 kg), feed intake is no longer a limiting factor. In fact, ADFI may exceed energy needs for lean accretion, resulting in increased carcass lipid content.

Schinckel (1992) predicted that the maximum rate of protein gain was attained between 40 and 50 kg, depending on genotype, nutrition, environment, and health status. However, lipid deposition continues to increase at heavier BW. Thus, in the growing pig, composition of gain is shifted toward greater carcass protein accretion as a result of increased dietary lysine intake. The resulting increase in lipid gain at similar rates of protein gain may be attributed to excess energy intake. Growing pigs (30 to 90 kg) selected for high protein gain tend to be energy-deficient for maximum protein deposition (Rao and McCracken, 1992), but the finishing pig (greater than 90 kg) seems to consume more energy than required for maximum protein deposition (Newcomb et al., 1993), resulting in greater lipid gain. Thus, the established lysine:calorie ratios from 3.0 to 3.2 g of lysine:Mcal of ME for growing pigs (Chiba et al., 1991 and Campbell and Taverner, 1988, respectively) may be overestimated for finishing pigs. The lysine:calorie ratios in our experiment ranged from 2.0 to 3.3 g/Mcal, indicating a need to evaluate the energy needs for pigs fed to heavier market weights (104 or 136 kg). The increase in protein deposition as digestible lysine increased from 72.5 to 136 kg may be a result of greater nonlean tissue growth (de Greef and Verstegen, 1993). This increase in protein gain might be a result of greater lipid gain and the association of protein to adipose tissue (Etherton et al., 1974). In our study, lipid deposition increased as BW increased; however, as a percentage of carcass composition, it was not influenced ($P > .10$) by digestible lysine at either 104 or 136 kg. Previous results of Shields et al. (1983) suggested that the percentage of carcass lipid increased linearly from 1.5 to 145 kg BW. This increase in carcass lipid is potentially associated with a greater feed intake (de Greef and Verstegen, 1993). In their experiment, as energy intake above maintenance increased from 12.6 to 16.3 Mcal of DE/d, whole-body lipid deposition was nearly 80 g/d greater. From 65 to 105 kg, 82% of the increased lipid deposition was associated with adipose gain and 18% with muscle gain. Thus, the greater lipid deposition rate at 136 kg in our study would be expected and may be attributed to the slightly greater feed intake (3%) compared to 104 kg. Campbell et al. (1984) and Friesen et al. (1994a) indicated that lipid deposition decreased as lysine intake increased from 45 to 90 and 34 to 72.5 kg, respectively.

Our initial hypothesis was that by increasing digestible lysine, in addition to carcass lipid characteristics, plasma cholesterol and triglyceride concentrations may be influenced. Analyses of lipid metabolism (plasma triglycerides and cholesterol), suggest that increased dietary lysine did not influence either plasma or tissue cholesterol content. These results are similar to those of Harris et al. (1993), who also reported that increased dietary fat or genotype (lean vs obese) did not affect longissimus muscle cholesterol content. This suggests that the homeostatic control of cholesterol metabolism was not regulated differentially by dietary lysine (Wheeler et al., 1987; Harris et al., 1993). Conversely, Park (1985) indicated that increasing dietary CP from 12 to 25% decreased plasma cholesterol in growing calves. Mersmann and MacNeil (1985) and Lukefahr et al. (1989) indicated poor correlations between plasma cholesterol and triglyceride content and tissue lipid concentration except for liver tissue. These results are similar to ours, in which plasma and tissue cholesterol concentrations were similar for gilts slaughtered at 104 and 136 kg.

Implications

These data demonstrate a greater dietary lysine requirement for high-lean growth gilts than current National Research Council estimates (19 g/d from 50 to 110 kg) for average daily gain (72 to 104 kg) and gain:feed (72 to 136 kg). Although carcass traits were minimally affected, maximum gain:feed was observed at approximately 21 g/d digestible lysine.

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