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The Impact of Feeding Diets of High or Low Energy Concentration on Carcass Measurements and the Weight of Primal and Subprimal Lean Cuts

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ABSTRACT : Pigs from four sire lines were allocated to a series of low energy (LE, 3.15 to 3.21 Mcal ME/kg) corn-soybean meal-based diets with 16% wheat midds or high energy diets (HE, 3.41 to 3.45 Mcal ME/kg) with 4.5 to 4.95% choice white grease. All diets contained 6% DDGS. The HE and LE diets of each of the four phases were formulated to have equal lysine:Mcal ME ratios. Barrows (N = 2,178) and gilts (N = 2,274) were fed either high energy (HE) or low energy (LE) diets from 27 kg BW to target BWs of 118, 127, 131.5 and 140.6 kg. Carcass primal and subprimal cut weights were collected. The cut weights and carcass measurements were fitted to allometric functions ($Y = A\ CW^B$) of carcass weight. The significance of diet, sex or sire line with A and B was evaluated by linearizing the equations by log to log transformation. The effect of diet on A and B did not interact with sex or sire line. Thus, the final model was cut weight = $(1+b_D(\text{Diet}))\ A(CW^B)$ where Diet = -0.5 for the LE and 0.5 for HE diets and A and B are sire line-sex specific parameters. Diet had no affect on loin, Boston butt, picnic, baby back rib, or sparerib weights ($p>0.10$, b_D = -0.003, -0.0029, 0.0002, 0.0047, -0.0025, respectively). Diet affected ham weight (b_D = -0.0046, p = 0.01), belly weight (b_D = 0.0188, p = 0.001) three-muscle ham weight (b_D = -0.014, p = 0.001), boneless loin weight (b_D = -0.010, p = 0.001), tenderloin weight (b_D = -0.023, p = 0.001), sirloin weight (b_D = -0.009, p = 0.034), and fat-free lean mass (b_D = -0.0145, p = 0.001). Overall, feeding the LE diets had little impact on primal cut weight except to decrease belly weight. Feeding LE diets increased the weight of lean trimmed cuts by 1 to 2 percent at the same carcass weight. (**Key Words :** Dietary Energy Concentration, Carcass, Pork, Primal Weight)

INTRODUCTION

The optimization of pork production systems including alternative dietary management and marketing strategies requires knowledge of pig feed intakes, growth rates, and estimated measures of carcass composition (de Lange and Schreurs, 1995; Schinckel et al., 2008). In the United States, high energy feed ingredients have been directed towards bioenergy production (i.e., corn to ethanol and animal fats to biodiesel). This has resulted in the formulation of diets with decreased energy concentration.

Genetic populations of pigs differ in their growth rates, daily energy intakes, and relative changes in carcass measurements (de Lange and Scheurs, 1995; Schinckel and de Lange, 1996). Genetic differences could also exist for the pigs' ability to use diets with different composition and energy concentration which could result in diet by genetic population differences in carcass composition. The objectives of this study were: i) to evaluate carcass measurements, primal and subprimal weights of pigs fed high and low energy density diets from 27 to 141 kg BW, and ii) to evaluate the magnitude of sire line by diet and sex by diet interactions for the carcass measurements and cut weights.

MATERIALS AND METHODS

Animal management and data collection

Animal procedures were consistent with the Guide for the Care and Use of Animals in Agricultural Research and Teaching FASS, 2010. Pigs were derived from a commercial sow farm and transported to Swine Tek, LLC

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for trial. Sires from four terminal sire lines with different rates of growth and body composition (Schinckel et al., 2012; lines1, 2, 3 and 4) were mated to PIC Cambrough sows. One group of sows was mated to the sires of each of the four sire lines each month. Ten monthly groups of sows (replicate) were bred from September 2008 to July 2009. Pigs were weaned at approximately 20 d of age and weighed one time at the nursery at an average of 50 d of age. All pigs were phase-fed the same nursery diets to an average age of 63 d at which time they were transported from the nursery facility to the Swine Tek research barns. Pigs were sorted into pens (12 pigs/pen) based on sire line and gender at arrival at the research building. Each pen had 7.62 m^2 of floor space to provide 0.635 m^2 per pig. Each pen was randomly assigned to either the high (HE) or low (LE) energy diets (Table 1) and to either a light or heavy market weight.

Diets were formulated to meet amino acid specifications that were established for these terminal sire lines (Pig Improvement Company, 2008), and vitamin and mineral levels met or exceeded those established by NRC (1998). Diet energy differences were established using either fat or wheat midds. The LE diets fed had 3.27 to 3.28 Mcal ME/kg, and 16% wheat midds. The HE diets (3.41 to 3.45 Mcal ME/kg) contained 4.5 to 4.95% choice white grease. All diets contained 6% DDGS. Diets were then balanced to a constant SID lysine:NRC ME ratio for each growth phase. The composition of each ingredient was determined prior to formulation (Schinckel et al., 2012). Ingredient NRC ME values were derived from the NRC (1998). Performance adjusted ME values (modified, MOD ME) were obtained from three nutrition companies, who discount the soybean meal NRC ME values (Schinckel et al., 2012).

The LE and HE diets were phase fed from the test date to completion of test. For replicates 1 to 6, the target BW's were 117.9 and 131.5 kg. For replicates 7 to 10, the target BW's were 127 and 140.6 kg. Pen feed intake data was collected each weigh day and when one or more pigs achieved its target BW and was removed from the pen and marketed.

Table 1. Diet composition (%) specifications for low and high energy diets

Low energy diets	Phase of growth[1]			
	Grower 1	Grower 2	Finisher 1	Finisher 2
Corn	52.20	54.37	62.90	63.55
Soybean meal, dehulled	23.15	21.40	12.9	12.45
Wheat middlings	16.0	16.0	16.0	16.0
Corn-DDGS	6.0	6.0	6.0	6.0
Limestone	1.24	1.20	1.18	1.16
Salt	0.40	0.40	0.40	0.40
L-lysine	0.325	0.30	0.30	0.175
DL-methionine	0.065			
L-threonine	0.070	0.075	0.074	0.014
Trace mineral premix[2]	0.075	0.075	0.075	0.075
Vitamin premix[3]	0.025	0.025	0.025	0.025
Potassium chloride	0.10	0.10	0.10	0.10
Copper sulfate	0.019			
Se premix	0.050	0.050	0.050	0.050
Antibiotic premix	0.278			
Calculated nutrients				
NRC ME (Mcal/kg)	3.271	3.273	3.275	3.277
NE (Mcal/kg)	2.356	2.375	2.400	2.421
NDF (%)	15.5	15.4	15.4	15.3
Total fat (%)	3.8	3.9	4.0	4.1
Lysine total (%)	1.22	1.09	0.95	0.82
Lysine, SID (%)	1.05	0.992	0.79	0.68
SID lysine:NRC ME	3.40	3.01	2.61	2.23
SID Threonine:Lysine	0.61	0.63	0.64	0.66
SID Trytophan:Lysine	0.17	0.18	0.18	0.19
SID Met+cystine:Lysine	0.55	0.58	0.62	0.65
Calcium (%)	0.76	0.73	0.70	0.67
Phosphorus available (%)	0.30	0.29	0.28	0.27

Table 1. Diet composition (%) specifications for low and high energy diets (Continued)

	Phase of growth[1]			
	Grower 1	Grower 2	Finisher 1	Finisher 2
High energy diets				
Corn	57.90	61.54	69.66	71.24
Soybean meal, dehulled	28.15	25.45	17.5	16.1
Corn-DDGS	6.00	6.00	6.00	6.00
Choice white grease	4.95	4.50	4.50	4.50
Limestone	1.125	1.095	1.07	1.06
Mono Ca-phosphate	0.40	0.315	0.265	0.245
Salt	0.40	0.40	0.40	0.40
L-lysine	0.325	0.300	0.275	0.175
DL-methionine	0.092	0.062	0.003	
L-threonine	0.085	0.088	0.076	0.0275
Trace mineral premix[2]	0.075	0.075	0.075	0.075
Vitamin premix[3]	0.025	0.025	0.025	0.025
Potassium chloride	0.10	0.10	0.10	0.10
Copper sulfate	0.049			
Se premix	0.05	0.05	0.05	0.05
Antibiotic premix	0.278			
Calculated nutrients				
NRC ME (Mcal/kg)	3.548	3.543	3.538	3.533
NE (Mcal/kg)	2.624	2.644	2.664	2.684
NDF (%)	11.2	11.1	11.1	11.0
Total fat (%)	8.1	8.1	8.0	8.0
Lysine total (%)	1.27	1.13	0.99	0.85
SID lysine (%)	1.16	1.02	0.89	0.77
SID lysine:NRC ME	3.40	3.01	2.61	2.23
SID Threonine:lysine	0.61	0.63	0.64	0.66
SID Trytophan:lysine	0.17	0.17	0.18	0.18
SID Met+cystine:lysine	0.55	0.58	0.60	0.63
Calcium (%)	0.76	0.73	0.71	0.68
Phosphorus available (%)	0.30	0.29	0.28	0.27

[1] Grower 1 from 27 to 58 kg BW, Grower 2 from 58 to 84 kg BW, Finisher 1 from 84 kg BW to 100 kg to target BW.

[2] Supplied per kg of diet: Fe, 100 mg ($FeSO_4$); Zn, 125 mg ($ZnSO_4$); Mn, 35 mg ($MnSO_4$); Cu, 15 mg ($CuSO_4$); I, 0.35 mg (EDDI); Se, 0.30 mg (Na_2Se).

[3] Supplied per kg of diet: vitamin A, 11,025 IU; vitamin D_3, 1,764 IU; vitamin E, 77 IU; vitamin K (menadione activity), 4.4 µg; riboflavin, 11 mg; D-pantothenic acid, 33 mg; niacin, 3.3 mg; vitamin B_{12}, 44.0 µg; thiamine, 3.3 mg; pyridoxine, 5.5 mg; folic acid, 1.21 mg; D-biotin, 276 µg.

Carcass measurements

The pigs were weighed in the morning of the day they were transported to a commercial processing plant. The pigs were loaded for transport in the early evening (about 1900) without any feed withdrawal. The pigs were held overnight in lairage for approximately 8 h before being harvested the following morning.

Backfat depth and loin depth measurements were taken with an optical probe 7 cm off-midline between the third and fourth from the last ribs. Carcass lean percentage (Lean %) was predicted using the equation used by the pork processor. Also an equation including carcass weight, loin depth and backfat depth was used to predict fat-free lean (FFL) percentage (FFL% = 60.8 -1.176 (backfat depth, mm) +0.127 (loin depth, mm)+0.011 (backfat depth mm)^2, Schinckel et al., 2010). Predicted fat-free lean percentage was multiplied by hot carcass weight to predict carcass fat-free lean mass. The weights of carcass primal and subprimal cuts for the left ham (three muscle ham) and left loin (baby back ribs, boneless loin, sirloin and tenderloin) were collected. In addition, weights were recorded for the trimmed and skinned Boston butt, picnic, and belly from the left side of each carcass.

Statistical analyses

The carcass data was fitted to a model including the random effect of replicate and fixed effects of sire line, sex, target BW, and the deviation of the actual BW from the

Table 2. Means, standard deviation and estimated variance due to replicate for the carcass traits

	N	Mean	SD	Variance due to replicate[1]	
				Estimate	Probability
Hot carcass weight (kg)	4,114	95.68	7.93	0.20	0.06
Backfat depth (mm)	4,101	18.50	4.30	0.64	0.06
Loin depth (mm)	4,070	66.49	6.87	0.30	0.11
Percent lean (%)	4,070	55.94	2.12	0.10	0.07
Predicted fat-free lean (%)	4,070	51.46	3.42	0.30	0.06
Predicted fat-free lean mass (kg)	4,070	49.16	4.56	1.53	0.001
Boston butt (kg)	4,041	4.07	0.491	0.012	0.06
Picnic (kg)	4,077	5.02	0.486	0.005	0.06
Belly (kg)	4,016	6.01	0.863	0.0346	0.06
Ham (kg)	4,077	11.32	0.968	0.010	0.07
Three-muscle boneless ham (kg)	4,066	5.95	0.644	0.025	0.06
Loin, bone in (kg)	4,071	12.31	1.22	0.003	0.12
Loin muscle boneless (kg)	4,069	4.49	0.461	0.0106	0.06
Tenderloin (kg)	3,986	0.509	0.077	0.0004	0.06
Sirloin (kg)	4,069	2.310	0.332	0.0032	0.06
Baby back ribs (kg)	4,034	0.969	0.112	0.0011	0.06
Spare ribs (kg)	4,044	2.183	0.304	0.0024	0.06

[1] Variance component due to replicate from model including overall effect of diet and sire line-sex specific allometric functions of BW for carcass weight and carcass weight for the carcass traits.

target BW as a covariate using the MIXED procedure of SAS® (SAS Institute, Inc., Cary, NC). The carcass measurement and cut weight data from the pigs were fitted to a linearized form of the allometric equation ($Y = A X^B$) by log to log transformation (log Y = log A+B log CW, where CW is carcass weight, Gu et al., 1992). The regression of the transformed variables was completed using the GLM procedure of SAS. The initial model included the effects of the diet, sire line and sex and interaction of the log CW with sire line, sex and diet. The significance of the sire line, sex and diet by log CW interactions were used to determine if the B values were different for the subgroups of pigs. The carcass measurement and carcass cut weight data were then fitted to a function of the allometric equations (based upon the significance of the interactions), diet effects and random effect of replicate using the nonlinear mixed (NLMIXED) procedure of SAS. The R^2 values were calculated as squared correlations between the predicted and actual observations.

RESULTS AND DISCUSSION

The means and standard deviations for the carcass variables are found in Table 2. Replicate was a source of variation accounting for 0.03 to 4% of the total variance of the carcass weight variables. The standard deviation for FFL % was greater (3.42 vs. 2.12%) than the standard deviation for Lean %. Replicate had significant affect (p = 0.001) on fat-free lean mass and accounted for 7.35% of the total variance.

The target BW least-squares means for the CWs and carcass measurements are shown in Table 3. Dressing percentage was not affected by target BW. Past researchers have found dressing percentage to increase as BW increased (Gu et al., 1992; Cisneros et al., 1996; Correa et al., 2006; Eggert et al., 2007). These genetic lines have reduced rates of fat accretion and are later maturing than pigs of the past

Table 3. Carcass measurement least squares for target bodyweight

	Target BW (kg)				Probability		
	117	127	131.5	140.6	SE	Sire line×BW	Sex×BW
Carcass weight	79.1	93.3	100.3	115.5	0.30	0.07	0.07
Dressing percentage	74.0	74.0	74.0	74.0	0.21	0.09	0.19
Backfat (mm)	15.8	13.2	19.1	22.5	0.46	0.50	0.44
Loin depth (mm)	62.5	66.1	63.5	71.0	0.49	0.48	0.55
Predicted lean (%)	56.6	56.0	56.0	54.8	0.21	0.73	0.72
Predicted fat-free lean (%)	53.0	51.7	51.2	49.1	0.36	0.71	0.72

Table 4. Main effect least squares for the carcass measurements

	Sire line					Diet		Sex			Probability		
	1	2	3	4	SE	High	Low	Barrow	Gilt	SE	Sire line	Sex	Diet
Hot carcass weight	97.6	96.0	98.7	96.7	0.22	97.6	96.7	97.2	97.1	0.18	0.001	0.19	0.021
Dressing percentage	74.4	73.1	75.2	73.4	0.16	74.4	73.7	74.1	74.0	0.13	0.040	0.07	0.039
Backfat (mm)	18.5	19.6	19.3	17.7	0.36	19.4	18.4	20.9	16.40	0.32	0.017	0.001	0.020
Loin depth (mm)	68.2	62.2	72.2	65.6	0.42	66.9	67.2	65.9	68.1	0.36	0.011	0.001	0.48
% Predicted lean	56.2	54.9	56.2	56.2	0.18	55.6	56.1	54.8	56.8	0.14	0.042	0.001	0.034
% Predicted fat free lean	51.7	50.1	51.2	52.0	0.28	50.8	51.6	49.6	52.9	0.23	0.031	0.001	0.028

trials (Schinckel et al., 2009). Backfat thickness and loin depth increased as BW increased. Both in-plant % Lean and FFL % decreased at relatively slower rates from 117 to 131.5 kg BW and relatively greater rates from 131.5 to 140.6 kg BW.

The main effects least-squares means for CW and carcass measurements are shown in Table 4. Hot CW and dressing percent were affected by sire line and diet ($p<0.05$). At the same BW, sire line 3 pigs had heavier CW and higher dressing percentage than pigs of the other three lines. Pigs fed the HE diets had heavier CW (97.6 vs. 96.7 kg, $p = 0.021$) and higher dressing percentage (74.35 vs. 73.67%, $p = 0.039$) than pigs fed the LE diets. High energy diets with added fat have had increased dressing percentage in some but not all research trials (Pettigrew and Moser, 1991; Eggert et al., 2007). Carr et al. (2005) found that pigs fed a barley-soybean meal-based diet (2.963 Mcal/kg) had a 1.1% lower dressing percentage than pigs fed a wheat-soybean meal-based diet (3.297 Mcal/kg, $p<0.05$).

Dressing percentage was slightly higher for barrows than for gilts (74.07 vs. 73.95%, $p = 0.07$). Cisneros et al. (1996) and Correa et al. (2006) found barrows and gilts had similar dressing percentages. Other researchers found gilts had higher dressing percentages than barrows (Latorre et al., 2004; Eggert et al., 2007; Schinckel et al., 2009). Gu et al. (1992) found significant sex by target BW interaction for dressing percentage with gilts having greater dressing percentage than barrows at 100 and 129 kg BW but not at 152 kg BW. Backfat depth was affected ($p<0.05$) by sire line, sex, and diet. Pigs fed the LE diets had less backfat depth (18.41 vs. 19.40 mm) than pigs fed the HE diets. Barrows had greater backfat depth than gilts (20.9 vs. 16.9 mm, $p<0.001$). Loin depth was affected ($p<0.05$) by sire line and diet. Pigs from sire line 3 had greater loin depths than pigs from the other sire lines (72.2 mm vs. 68.2, 62.2 and 65.6 mm for pigs from sire lines 1, 2, and 4 respectively). Overall, loin depth was not affected by diet ($p = 0.48$). Gilts had greater loin depth than barrows (68.1 vs. 65.9 mm, $p<0.001$).

Overall % Lean was affected by diet (LE = 56.1% versus HE = 55.9%, $p = 0.034$) and sex (Gilts = 56.8 vs. Barrows = 54.9%, $p<0.001$). Overall, FFL % was affected by diet (50.8 and 51.6% for the HE and LE diets, $p = 0.028$) and sex (49.6% and 52.9% for barrows and gilts, $p<0.001$). Other researchers have found the addition of fat to swine diets increased backfat depth and reduced predicted carcass lean percentage (Moser, 1991; De la Llata et al., 2001; Pettigrew and Weber et al., 2006).

There were significant ($p<0.01$) sire line by sex interactions for backfat depth, loin depth, Lean % and FFL % (Table 5). The difference in backfat depth between sire line 4 barrows and gilts (3.3 mm) was less than the barrow-gilt differences observed in the other lines (4.5, 4.4 and 4.1 mm). The difference in loin depth between the barrows and gilts of sire line 2 (1.4 mm) and sire line 4 (1.6 mm) was less than that observed for sire lines 1 and 3 (3.2 and 3.0 mm). The differences between the barrows and gilts for Lean % were 2.1, 2.0, 2.1 and 1.7% for the pigs of sire lines 1 to 4, respectively. The differences between barrows and gilts for FFL % were 3.8, 2.5, 3.3, and 2.9% for the pigs of sire lines 1 to 4, respectively. There were no interactions of diet ($p>0.20$) with sire line, sex, or target BW.

Schinckel et al. (2009) found sire line by sex interactions ($p<0.01$) existed for both live animal ultrasonic and optical probe backfat depths, loin depths, and predicted Lean %. In general, the differences between barrows and gilts for backfat depth and predicted Lean % are greater in genetic populations with greater backfat depths and

Table 5. Sire line by sex interactions for carcass traits

Sire line	1		2		3		4		SE	Prob.
Sex	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt	Barrow	Gilt		
Backfat (mm)	20.9	16.4	21.8	17.4	21.9	17.8	19.3	16.0	0.40	0.005
Loin depth (mm)	66.6	69.8	61.5	62.9	70.7	73.7	64.8	66.4	0.50	0.002
Lean (%)	55.1	57.2	53.9	55.9	55.1	57.2	55.3	57.0	0.19	0.002
Fat-free lean (mm)	49.9	53.7	50.3	52.8	49.5	52.8	50.5	53.4	0.34	0.014

decreased percent lean (Wagner et al., 1999). For example, the differences in backfat depth between barrows and gilts of three genetic populations of pigs were 9.7 (49.3 vs. 39.6), 2.5 (27.9 vs. 25.4) and 5.6 mm (39.3 vs. 33.7) at 128 kg BW (Wagner et al., 1999).

Carcass weight had a strong relationship to BW (R^2 = 0.931, Table 6). The parameters for the allometric function relating CW to BW were impacted by sire line and sex ($p<0.05$). Diet also effect CW relative to BW (B_D = 0.097, $p<0.001$) with pigs fed the HE diets having about 1% greater CW then pigs fed the LE diets at the same BW.

The parameters for the allometric functions relating loin depth, backfat depth, Lean % and fat-free lean mass to CW are shown in Table 7. Significant sire line by sex interactions existed for allometric equation parameters, (A for loin depth, B for backfat depth, and both A and B for Lean % and fat-free lean mass). The R^2 and RSD values indicate that substantial variation existed for these variables even when pigs were of the same sire line, sex, diet, and CW.

At 100 kg CW, the mean predicted increases in backfat depth per kilogram increase in CW was 0.156 and 0.175 mm for the gilts and the barrows. The optical probe data of a previous pig growth trial (Wagner et al., 1999; Schinckel et al., 2001) was fitted to an allometric function of CW. At 100 kg CW the predicted increases in backfat depth for the gilts and barrows were 0.266 and 0.322 mm per kilogram increase in CW. At 100 kg CW, the predicted increases in loin depth for the gilts and barrows were 0.289 and 0.276 mm per kilogram increase in CW. These values are greater than those in the previous trial (Wagner et al., 1999) with predicted increases in loin depth of 0.124 and 0.121 mm for gilts and barrows at 100 kg CW.

Table 6. Parameters for allometric function describing the relationship of carcass weight to BW[1]

Sire line	Sex	A	B
1	Barrow	0.720	1.006
1	Gilt	0.773	0.9916
2	Barrow	0.600	1.044
2	Gilt	1.012	0.933
3	Barrow	0.711	1.011
3	Gilt	0.774	0.994
4	Barrow	0.647	1.026
4	Gilt	0.651	1.024
	Diet effect	0.0097	
	Pooled SE		0.013
	Probability		
	Sire line	0.037	0.048
	Sex	0.001	0.001
	Sire line by sex	0.34	0.45
	Diet	0.001	0.29
	R^2	0.931	
	RSD (kg)	2.09	

[1] The final model included random effect of replicate the overall effect of diet and sire line - sex specific allometric functions ($Y = AX^B$).
Function has form hot carcass weight = $(1+b_D D) A(BW)^B$ where D is -0.5 for low energy and 0.5 for high energy diets.

Table 7. Allometric function relating carcass measurement to carcass weight

Sire line	Sex	Loin depth (mm)		Backfat (mm)		Percent lean		Fat-free lean mass (kg)	
		A	B	A	B	A	B	A	B
1	Barrow	11.50	0.3830	0.2019	1.007	85.3	-0.0952	1.380	0.777
1	Gilt	11.29	0.3976	1.153	0.576	59.4	-0.0079	0.0751	0.926
2	Barrow	6.48	0.4932	1.223	0.631	62.9	-0.0339	0.821	0.884
2	Gilt	5.94	0.5173	0.281	0.904	66.9	-0.0394	1.023	0.851
3	Barrow	12.84	0.3712	0.326	0.917	81.5	-0.0852	1.237	0.800
3	Gilt	14.93	0.3474	0.166	1.016	78.8	-0.0695	1.286	0.806
4	Barrow	9.65	0.4170	0.681	0.732	67.5	-0.0433	0.933	0.866
4	Gilt	9.53	0.4253	0.101	1.108	75.9	-0.0627	1.295	0.806
	Diet effect	-0.0086		0.0479		-0.0081		-0.0145	
	Pooled SE		0.040		0.10		0.025		0.26
	Probability								
	Sire line	0.057	0.10	0.17	0.18	0.057	0.11	0.043	0.041
	Sex	0.42	0.14	0.02	0.10	0.42	0.14	0.001	0.20
	Sire line×sex	0.0004	0.21	0.13	0.002	0.004	0.008	0.002	0.002
	Diet	0.009		0.001		0.001		0.001	
	R^2	0.354		0.413		0.362		0.683	
	RSD	5.53		3.30		1.70		2.57	

[1] The final model included random effect of replicate the overall effect of diet and sire line - sex specific allometric functions ($Y = AX^B$).
Function has form hot carcass weight = $(1+b_D D) A(CW)^B$ where D is -0.5 for low energy and 0.5 for high energy diets. CW is carcass weight and A and B are sire-line sire specific Allometric equation.

At 100 kg CW, the Lean % was predicted to decrease 0.035% per kilogram increase in CW for the barrows and 0.021% per kilogram increase in CW for the gilts. The significant sire line by sex interactions for the allometric equations indicated that the sex differences in which Lean % decreased per kilogram in CW differed amongst the 4 sire lines. This requires separate evaluation and modeling of the pigs of each sire line and sex to predict the changes in lean % associated with estimated carcass value as CW increases.

At 100 kg CW, the fat-free lean mass was predicted to increase 0.446 kg per kilogram increase in CW for the gilts and 0.410 kg per kilogram increase in CW for the barrows. The significant sire line by sex interactions for the allometric equations indicated the sex differences in which fat-free lean mass decreased per kilogram in CW differed amongst the 4 sire lines. The predicted increases in fat-free lean mass (kg) per kilogram increase in CW at 100 kg CW were 0.386 and 0.495 for sire line one; 0.425 and 0.438 for sire line 2; 0.395 and 0.425 for sire line 3 barrows and 0.435 and 0.427 for sire line 4 barrows and gilts, respectively. The amount of fat-free lean gain per kilogram increase in CW or BW gain determines to a large extent the pig's lysine requirements relative to energy intake (NRC, 1998; Schinckel et al., 2001). The results indicate that the sex differences in compositional growth and lysine requirements (g/Mcal ME or NE) may be greater for pigs by sire line 1 than the other sire lines especially when combined with the differences observed in daily NE or ME intakes (Schinckel et al., 2012).

The parameters of the allometric functions relating the weight of the primal and subprimal cut weights to CW in several cases were affected by sire line, sex and sire line by sex (Tables 8 and 9, $p<0.05$). Thus for consistency, all primal and subprimal weights were fitted to sire line-sex specific allometric equations.

The value of the B parameter indicates the percentage increase in the primal or subprimal cut weight per percentage increase in CW. The spare rib and belly weights had B values greater than 1 which indicate that the weights of these cuts increased at a relatively greater rate than carcass and that their percentage of total CW increased as CW increased. The ham, picnic, baby back rib and three muscle ham weights had B values less than one which indicates as a percentage of CW, the weights of these cuts decreased as CW increased. Crome et al. (1996) found that from 107 to 125 kg BW, the carcass percentage of belly weight increased from 16.64% to 17.86% and the carcass percentage of picnic weight decreased from 10.68 to 9.81% ($p = 0.001$). Cisneros et al. (1996) also found the carcass percentage of ham and picnic cut weights decreased as CW increased. In contrast, Cisneros et al. (1996) did not find any significant increase in belly weight or sparerib weight as a percentage of CW as CW increased. The pigs of Cisneros et al. (1996) had greater backfat depths than the pigs in this trial, approximately 31.3 mm at 128 kg BW.

Table 8. Allometric functions relating primal cut weights to carcass weight

Sire line	Sex	Ham (kg)		Loin bone in (kg)		Boston butt (kg)		Picnic (kg)		Spareribs (kg)		Belly (kg)	
		A	B	A	B	A	B	A	B	A	B	A	B
1	Barrow	0.2517	0.833	0.0915	1.074	0.0619	0.915	0.1436	0.7780	0.0126	1.130	0.0141	1.331
1	Gilt	0.2485	0.841	0.1059	1.042	0.0414	1.010	0.0941	0.8712	0.0108	1.162	0.0194	1.253
2	Barrow	0.1845	0.895	0.1175	1.019	0.0509	0.961	0.1427	0.7785	0.0104	1.182	0.0123	1.362
2	Gilt	0.1861	0.899	0.1547	0.958	0.0511	0.964	0.1404	0.7847	0.0112	1.161	0.0154	1.308
3	Barrow	0.2323	0.852	0.1470	0.974	0.0720	0.882	0.1331	0.7912	0.0142	1.096	0.0116	1.371
3	Gilt	0.2854	0.815	0.1248	1.009	0.0659	0.902	0.1039	0.8477	0.0077	1.227	0.0114	1.368
4	Barrow	0.1919	0.892	0.1050	1.043	0.0368	1.031	0.1411	0.7868	0.0120	1.142	0.0153	1.311
4	Gilt	0.2940	0.803	0.1182	1.018	0.0503	0.965	0.1163	0.8308	0.0123	1.133	0.0086	1.430
	Diet effect	-0.0046		-0.0029		-0.009		0.0002		-0.003		0.0188	
	Pooled SE		0.023		0.024		0.051		0.047		0.039		.007
	Probability												
	Sire line	0.090	0.14	0.050	0.057	0.19	0.17	0.71	0.74	0.87	0.86	0.41	0.45
	Sex	0.011	0.44	0.21	0.20	0.80	0.76	0.08	0.07	0.48	0.60	0.65	0.80
	Sire line×sex	0.099	0.046	0.42	0.38	0.10	0.14	0.44	0.50	0.60	0.55	0.60	0.72
	Diet	0.010		0.10		0.28		0.524		0.41		0.001	
	R^2	0.708		0.727		0.506		0.551		0.305		0.686	
	RSD	0.520		0.639		0.344		0.334		0.094		0.484	

[1] The final model included random effect of replicate the overall effect of diet and sire line - sex specific allometric functions ($Y = AX^B$).

Function has form hot carcass weight = $(1+b_D D)\ A(CW)^B$ where D is -0.5 for low energy and 0.5 for high energy diets. CW is carcass weight and A and B are sire-line sire specific Allometric equation.

Table 9. Allometric functions relating the subprimal cut weights to carcass weight

Line	Sex	Three-muscle boneless ham (kg)		Trimmed boneless loin (kg)		Sirloin (kg)		Tender loin (kg)		Baby back ribs (kg)	
		A	B	A	B	A	B	A	B	A	B
1	Barrow	0.1400	0.8187	0.1323	0.7704	0.01057	1.173	0.01514	0.765	0.01958	0.854
1	Gilt	0.1386	0.8364	0.0773	0.8961	0.02409	1.000	0.00620	0.972	0.01764	0.883
2	Barrow	0.1043	0.8689	0.0608	0.9321	0.02905	0.991	0.00621	0.947	0.05306	0.634
2	Gilt	0.1299	0.8351	0.0888	0.8571	0.03002	0.958	0.01360	0.791	0.06230	0.602
3	Barrow	0.1099	0.8698	0.1155	0.8045	0.03251	0.930	0.00584	0.977	0.02569	0.789
3	Gilt	0.1896	0.7666	0.0555	0.9755	0.03324	0.930	0.00432	1.060	0.06297	0.596
4	Barrow	0.1454	0.8077	0.1323	0.8943	0.02513	0.990	0.00654	0.946	0.02524	0.799
4	Gilt	0.2429	0.7084	0.0773	0.9635	0.02263	1.015	0.01003	0.869	0.04057	0.697
	Diet effect	-0.0140		-0.0101		-0.0091		-0.0225		0.048	
	Pooled SE		0.038		0.036		0.006		0.059		0.005
	Probability										
	Sire line	0.091		0.029		0.089	0.11	0.25	0.18	0.001	0.001
	Sex	0.012		0.030		0.33	0.039	0.82	0.88	0.035	0.046
	Sire line×sex	0.099		0.26		0.19	0.24	0.18	0.42	0.007	0.089
	Diet	0.001		0.001		0.034		0.001		0.14	
	R^2	0.571		0.611		0.355		0.384		0.403	
	RSD	0.421		0.289		0.0689		0.061		0.008	

[1] The final model included random effect of replicate the overall effect of diet and sire line - sex specific allometric functions ($Y = AX^B$).
Function has form hot carcass weight = $(1+b_D D) A(BW)^B$ where D is -0.5 for low energy and 0.5 for high energy diets.

Correa et al. (2006) found that belly weight increased as a percentage of CW as BW increased from 107 to 125 kg for the barrows and not for the gilts (sex by BW interaction, $p<0.05$).

Selection for increased leanness and feed efficiency may have selected pigs with decreased fat accretion, increased muscle accretion, and delayed fat accretion which may have changed the relative increases in primal and subprimal cut weights (Wiseman et al., 2007; Hermesch, 2008; Schinckel et al., 2008). Weights of the primal and subprimal cuts, adjusted for BW, are heritable and genetically correlated to carcass and live animal measurements including backfat depth, loin depth, predicted percent lean (van Wijk et al., 2005; Hermesch, 2008).

The R^2 of the prediction for the primal and subprimal lean cut weights ranged from 0.305 to 0.727. Mérour and Hermesch (2008) reported that within each genetic population and sex, CW accounted for approximately 63% of the variation in ham weight, 57% of the variation in trimmed loin weight and 48% of the variation in belly weight. These R^2 and RSD values indicate the weights of the primal and subprimal cuts have substantial variation even within pigs of the same sire line, sex and BW. Closely sorting of pigs based on BW can result in decreased variation in CW but will only partially reduce the variation in the primal cut weights and measurements (Schinckel et al., 2003).

The market value of a pork carcass is a function of the weight of each primal or subprimal cuts times the value of each cut (Akridge et al., 1992; Marcoux et al., 2007). If the values of the primal and subprimal cuts per kg are based on specific weight classes, then stochastic models of the carcass cut weights will be needed to model the mean and variation in the carcass value as functions of genetic population, diet and CW.

Diet affected the weights of several of the primal and subprimal cuts. Diet affected ham (b_D = -0.0046, p = 0.01) and belly weight (b_D = 0.0188, p = 0.001). Diet had no impact on wholesale loin, Boston butt, picnic, baby back rib, or sparerib weights ($p>0.10$, b_D = -0.003, -0.009, 0.0002, 0.048, -0.0025, respectively). Three muscle ham weight was affected by diet (C = -0.014, p = 0.001) as was boneless loin (C = -0.010, p = 0.001), tenderloin (b_D = -0.023, p = 0.001) and sirloin weight (b_D = -0.009, p = 0.034). Diet also affected predicted fat-free lean mass (b_D = -0.0145, $p<$ 0.001). In contrast other researchers have found that the addition of 5% fat to corn-soybean meal based diets did not affect the carcass percentage of any primal cut (Eggert et al., 2007; Apple et al., 2009). It should be noted that the large number of pigs in this trial allow relatively small treatment effects to be precisely estimated. Also, in this trial the energy content between the LE and HE diets was greater than the past trials as the addition of wheat midds decreased the energy content and increased the fiber content of the LE diets.

One objective of this trial was to evaluate the possible interactions of sire line and sex with diet. Overall, these interactions were not significant indicating that the effects of diet energy content on carcass measurements and carcass cut weights were similar across the four sire lines and two sexes. The feeding of LE diets is expected to increase carcass leanness and weights of lean cuts and reduce the weight of bellies similar amounts in commercially available genetic lines of pigs. Sex by sire line interactions were significant for several carcass measurements and cut weights indicating the carcass composition differences between barrows and gilts differ amongst different sire lines. The compositional growth of each sire line and sex population must be evaluated and modeled to evaluate alternative marketing strategies.

IMPLICATIONS

Sire lines can be chosen to target specific growth for measurements, predicted percent lean, weight of primal and subprimal cuts. The feeding of diets with decreased energy content increased the predicted lean percentage of the pigs across all sire lines in this trial. The differences observed between barrows and gilts differed amongst the sire lines. The carcass measurements, primal and subprimal cut weights can be modeled as functions of genetic population, sex, diet, and BW. However, even at constant BW or CW, substantial variation exists for the carcass measurements and cut weights.

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