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ARTICLE

Effects of the Plane of Nutrition on Physicochemical Characteristics and Sensory Quality Traits of the Muscle in Finishing Pigs

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Abstract

This study was performed to examine the feasibility of using the low plane of nutrition (LPN) as a means of improving the meat quality of crossbred finishing pigs with a medium weight gain potential. Twenty-four barrows and 24 gilts weighing approximately 48 kg were placed on LPN [a finisher (2.86 Mcal ME/kg and 0.67% lysine) for 91 d] or on a high plane of nutrition [HPN; a commercial grower for 38 d and a finisher (3.35 Mcal ME/kg and 0.9% lysine) for 46 d]. Five barrows and five gilts per treatment weighing approximately 125 kg were slaughtered after the indicated days on the respective diets, followed by physicochemical analysis and sensory evaluation on their muscles. Overall average daily gain was 12.6% less in the LPN group vs. the HPN group (p<0.05). The redness (a*) of fresh longissimus muscle (LM) from the loin as well as from Boston butt was greater in the LPN group vs. HPN whereas the shear force for fresh LM from these primals and semimembranosus muscle was lower in the former. In sensory evaluation for cooked LM, no treatment effect was detected in any of the quality traits examined, except for a lower color score in the LPN vs. HPN group. Results suggest that meat quality of the finishing pigs can be improved to some extent by using LPN. However, the present pigs, whose backfat thickness was 24 mm at 125 kg, are thought not to be lean enough to be fattened over 120 kg.

Keywords: finishing pig, plane of nutrition, physicochemical characteristics, meat quality, sensory evaluation

Introduction

Growth rate and body composition as well as physicochemical characteristics and sensory quality traits of the muscles of finishing pigs are determined by genetics, sex, nutrition, slaughter weight, and others (Ellis *et al*., 1996; Pettigrew and Esnaola, 2001; Schinckel *et al*., 2012; Sutton *et al*., 1997). Pig breeding has been aimed primarily at increasing the litter size and lean/weight gain as well as decreasing fat deposition represented by backfat thickness and thereby increasing the production efficiency, especially feed efficiency. This has often resulted in a decrease in some meat quality traits including water-holding capacity and marbling (Huff-Lonergan *et al*., 2003; Sonesson *et al*., 1998; van Wijk *et al*., 2005). Given the genetic background, the rate of weight gain as well as backfat thickness, which is greater in barrows than in gilts, increases with the increasing plane of nutrition or dietary energy density (Correa *et al*., 2006; de Lange *et al*., 2001; Lee *et al*., 2002).

Jeong *et al*. (2010) have analyzed the relationships of the meat quality traits to the dietary energy density and slaughter weight between 110 kg and 135 kg in pigs with a high lean gain potential using pooled data from previous studies of Lee *et al*. (2006, 2007) and Park *et al*. (2007, 2009a, 2009b). Following are the main results of their analysis. The redness [CIE (1986) a*] and subjective marbling and overall acceptability scores for fresh loin were positively correlated with the slaughter weight. In addition, the a* value of fresh loin also increased when the animals were fed a low-energy diet containing 3.0 Mcal DE/kg vs. a control diet (3.2 Mcal DE/kg). Overall scores of the sensory quality traits for fresh and cooked loin, Boston butt and ham increased slightly between 110- and 125-kg live weights, and did not change signifi-

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cantly between 125 and 135 kg. In contrast to this, in finishing pigs with a low weight/lean gain potential, physiochemical characteristics and sensory quality scores including the redness and marbling of fresh and cooked loin were not influenced by the dietary energy density between 3.0 and 3.4 Mcal DE/kg in the study of Ha *et al.* (2010). On the other hand, it could not be determined in that study whether or not meat quality could be improved by using the low-energy diet and thereby increasing the slaughter weight to 125 kg or greater, because the pigs were almost over-fat at approximately 115 kg of body weight, the average slaughter weight in Korea in recent years (KPPA, 2014), and therefore were slaughtered at that weight. As such, effects of the dietary energy density on meat quality of medium-lean finishing pigs slaughtered at a high body weight are unknown. The present study was therefore performed to investigate the feasibility of improving the pork quality by using the low plane of nutrition and thereby slaughtering at a high body weight in finishing pigs with a medium weight gain potential. To this end, the medium-lean pigs used in the present study were slaughtered at 125 kg of predetermined weight, which was the median between 135 and 115 kg of subjectively assessed maximum slaughter weights for the aforementioned high- and low-lean pigs, respectively, based on their carcass and meat quality after the finishing phase on the medium-energy diet (3.2 Mcal DE/kg).

Materials and Methods

Animals

The experimental protocol for this study conformed to the guideline of Institutional Animal Care and Use Committee (IACUC) at Gyeongnam National University of Science and Technology. The animals used in the present study were handled humanely and also did not receive any prolonged constraint throughout the experiment.

Out of a number of pens of 108-d-old (Yorkshire×Landrace)×Duroc pigs with a medium weight gain potential, 2 barrow pens and 2 gilt pens were chosen arbitrarily and 12 animals weighing approximately 48 kg were selected out of 17 animals in each of the four selected pens. The present experiment was performed under a 2 (sex)×2 (plane of nutrition; 'high' vs. 'low') arrangement of treatments in which each 24 selected animals consisting of equal numbers of barrows and gilts in two respective pens received a low-plane finisher diet containing 2.86 Mcal ME/kg for 91 d or a commercial grower for 38 d followed by a high-plane finisher (3.35 Mcal ME/kg) for 46 d

Table 1. Composition of the diets of varying planes of nutrition used in the present study (as-fed basis)

Component	Grower[1)]	Finisher[2)]	
		Low	High
Crude protein (%)	16.6	13.0	16.5
Lysine (%)	1.0	0.67	0.90
Crude fat (%)	5.0	2.93	7.19
DE (Mcal/kg)	3.45	3.06	3.60
ME (Mcal/kg)	-	2.86	3.35

[1)]Commercial diets; declared minimum.
[2)]Corn-wheat-soybean meal-based diets manufactured for the present experiment; calculated composition.

(Table 1). The high- and low-plane finishers were formulated to meet the nutrients densities including the lysine concentration suggested by NSNG (2010) and NRC (2012) for finishing pigs with high and low lean gain potentials, respectively.

Body weight was measured on d 0, 38, and 69 of the experiment in all animals and on d 84 and 91, the last days on feed for the high-plane and low-plane groups, respectively. Five barrows and five gilts per treatment weighing approximately 125 kg were fasted overnight following the measurement of their final weights, after which the animals were transported to a local abattoir for 40 min and slaughtered after a 3-h lairage. Feed intake was not measured, partly because the present feeding trial was performed on a commercial farm using a mechanical feeder system, partly because only selected animals in each pen were used as experimental units.

Physicochemical analysis of the muscle

After the measurement or evaluation of the weight, backfat thickness, and others on the hot carcass by the grading official (MAFRA, 2014), the carcass was chilled for 24 h at 2±2°C and fabricated according to the standard of MFAS (2013). The loin comprising the longissimus muscle (LM) widely used as the representative muscle for physicochemical analysis and sensory evaluation (Judge *et al*., 1989) as well as a second representative lean primal ham was removed from the carcass. In addition, Boston butt containing the upper part of the LM, which contains more intramuscular fat than the LM of the loin (Clausen and Ovesen, 2001; Kang *et al*., 2011), was also taken as another type of muscle for its higher fat content. The loin, Boston butt, and ham were transported to the laboratory and the LM and semimembranosus muscle (SM) were removed from the former two primals and ham, respectively, for physicochemical analysis and sensory evaluation on the muscle described below.

Physicochemical characteristics of the fresh and cooked muscles were determined basically as described previously (Jin *et al*., 2004; Lee *et al*., 2002). Briefly, the color of fresh muscle and backfat was measured by the CIE (1986) L* (lightness), a* (redness) and b* (yellowness) standards using a chromameter (CR-40, Minolta Co., Japan) calibrated to the white plate (L*=93.5; a*=0.3132; b*=0.3198). The pH was measured on a homogenate of the muscle in a 9 volume of distilled water (w/v). Drip loss was determined by measuring the weight loss of a 2-cm muscle slice during 24-h suspension at 4°C in a polypropylene bag. The shear force was measured using Instron 3343 (US/MX50, A&D Co., USA) on a 9.5 mm-diametral muscle core which had been prepared by longitudinally probing the muscle, with the chart speed, maximum load, and measure speed set at 120/min, 10 kg, and 60 mm/min, respectively. Textural properties of cooked muscle were measured after heating a muscle sample cut to a 4-cm thickness and a 6-cm length in a water bath at 80°C for 1 h and cooling it at 4°C for 2 h in a polypropylene bag. Cooking loss was defined by the difference in muscle weights before and after the heating and cooling; firmness and chewiness were measured on the cross-section of the cooked muscle sliced to a 2-cm height; shear force was measured as in fresh muscle.

Contents of moisture, protein and fat of the muscle were determined by the oven-drying, Kjeldahl and Soxhlet extraction methods, respectively, according to the AOAC (2007) procedures. Composition of fatty acids was determined by gas chromatography using the AT - Silar capillary column (Alltech, USA) after extraction of total lipids by the method of Folch *et al*. (1957), with operation conditions set at 230°C of initial temperature (T), 250°C of injector T, 240°C of detector T, 2°C/min of programming rate, 50 mL/min of flow rate, and 100:1 of split ratio.

Sensory evaluation

Sensory quality traits of the LM of fresh loin and Boston butt and the SM of the ham were evaluated according to the 9-notch whole-number point scale (Jin *et al*., 2004; Park *et al*., 2007, Park *et al*., 2009a) by six panelists trained in the meat science lab of the present workers as described by Meilgaard *et al*. (1991). Fresh meat was given the arbitrary point 1 to 9 for each of its quality attributes ranging from "very poor meat color; undetectable marbling; severe off-odor; severe dripping, and very poor overall acceptability" to "superb meat color; superb marbling; no off-odor; little dripping; and superb overall acceptability." As for cooked muscle, only the LM of the loin, which is widely used as the representative muscle for this purpose (Bredahl *et al*., 1998), was cooked and evaluated by the analogous criteria for color, aroma, taste, juiciness, tenderness, and overall palatability. To be brief, each sensory attribute was scored in such a way that a greater point indicates a better quality.

Statistical analysis

All data were analyzed by the General Linear Model procedure included in the SAS (2008) statistical software package. The statistical model included sex, plane of nutrition, and an interaction of them, as well as the panelist in sensory evaluation, as fixed errors, with individual animal defined as the error term (experimental unit). Effects of the treatment, sex, and their interaction with $p \leq 0.05$ were judged as significant. Means were compared using the PDIFF option only when the *p*-value for the fixed error or the interaction of the fixed errors was 0.05 or less.

Results

Growth performance

Body weights of the animals on d 0 and 38 of the experiment and average daily gain (ADG) during the initial 38 d did not differ between the animals placed on the low plane of nutrition (LPN) and those on the high plane of nutrition (HPN) or between barrows and gilts (Table 2). However, ADG during d 38-69 and 69-84 (for HPN) or -91 (for LPN) were greater in the HPN group than in the LPN group ($p<0.05$ and $p<0.01$, respectively). Overall ADG also was greater in the HPN vs. LPN group (897 g vs. 785 g; SE=19 g; $p<0.01$). However, neither of the effects for the sex and sex × treatment interaction on ADG was significant during any period of the experiment.

Physicochemical characteristics of the muscle

Of those animals whose muscles were used for physicochemical analysis and sensory evaluation, the HPN group had a greater live weight and a greater carcass weight than the LPN group, although the live and carcass weights were within 125±2.5 kg and 96.0±2.5 kg, respectively, in all of the four experimental groups (Table 3). Dressing percentage and backfat thickness, however, did not differ between the HPN and LPN groups or between the barrow and gilt groups.

The L* value of the LM from the loin did not differ between the HPN and LPN groups or between barrows and gilts. The a* value of the loin LM was greater in the

Table 2. Effects of the plane of nutrition on growth of finishing pigs

Variable	Low plane[1)]		High plane[2)]		SEM	*P*-value		
	B[3)]	G[3)]	B[3)]	G[3)]		N[4)]	S[4)]	N×S
Body wt (kg)								
Day 0	48.6	45.6	48.7	49.0	1.7	0.31	0.44	0.34
Day 38	82.5	80.6	82.9	82.6	1.4	0.37	0.45	0.54
Day 69	106.2	104.4	111.1	108.5	1.9	0.02	0.24	0.84
Day 84/91	120.5	115.0	125.0	122.9	2.3	0.01	0.11	0.49
ADG (g)								
Day 0-38	892	923	899	885	36	0.67	0.81	0.53
Day 38-69	807	785	912	834	32	0.02	0.12	0.39
Day 69-84/91	649	482	956	957	67	<0.01	0.22	0.21
Overall	797	771	915	879	27	<0.01	0.26	0.86

[1)]Fed the low-plane finisher (Table 1) throughout the experiment (d 0-91).
[2)]Fed the grower and high-plane finisher during d 0-38 and 38-84, respectively.
[3)]B, barrow; G, gilt. Data are means of 12 animals.
[4)]N, plane of nutrition; S, sex.

Table 3. Physicochemical characteristics of the *longissimus dorsi* muscles of finishing pigs which were placed on either the low or high plane of nutrition

Variable	Low plane[1)]		High plane[2)]		SEM	*P*-value		
	B[3)]	G[3)]	B[3)]	G[3)]		N[4)]	S[4)]	N×S
Live wt (kg)	124.1	122.9	127.3	125.5	1.3	0.04	0.28	0.80
Carcass wt (kg)	96.6	94.2	98.4	98.2	1.4	0.05	0.35	0.43
Dressing (%)	77.9	76.6	77.3	78.3	0.7	0.45	0.83	0.12
BFT[4,5)] (mm)	26.0	22.0	24.5	24.9	1.8	0.71	0.32	0.23
				Fresh muscle				
Color								
CIE L* (muscle)	59.2	55.4	56.1	54.5	1.5	0.20	0.09	0.47
CIE a* (muscle)	9.37	9.64	8.18	7.84	0.60	0.02	0.95	0.62
CIE b* (backfat)	3.47	3.94	4.49	4.43	0.26	0.01	0.44	0.33
pHu	5.83	5.73	5.68	5.70	0.04	0.04	0.26	0.16
Drip loss (%)	4.81	6.27	7.28	6.11	0.62	0.08	0.82	0.05
Shear force (kg/cm^2)	3.29	3.17	5.74	5.62	0.50	<0.01	0.81	1.00
Moisture (%)	73.1	74.2	73.5	74.3	0.2	0.28	<0.01	0.60
Crude protein (%)	22.83	22.12	22.99	22.57	0.44	0.49	0.21	0.75
Crude fat (%)	1.97	1.45	1.73	1.42	0.21	0.54	0.07	0.65
				Composition of fatty acids (%)				
18:0	13.79	13.59	13.21	13.08	0.45	0.24	0.72	0.93
18:1	44.53	45.24	44.36	44.01	0.80	0.40	0.82	0.52
18:2	6.38	7.89	8.08	9.12	0.76	0.07	0.11	0.76
20:4	1.17	1.76	1.44	1.69	0.26	0.69	0.12	0.52
SFA[4)]	42.85	40.63	41.34	40.63	0.81	0.36	0.09	0.36
PUFA[4)]	8.54	10.82	10.63	11.92	1.02	0.14	0.10	0.63
n-3	0.91	1.08	1.01	1.00	0.04	0.88	0.05	0.04
				Cooked muscle				
Cooking loss (%)	42.9	43.5	42.6	43.2	0.7	0.72	0.44	0.99
Shear force (kg/cm^2)	4.91	5.81	5.04	4.77	0.47	0.34	0.50	0.23
Firmness (kg/cm^2)	1.63	1.87	1.39	1.72	0.15	0.21	0.08	0.76
Chewiness (kg)	1.09	0.98	0.63	0.89	0.21	0.21	0.71	0.40

[1)]Fed the low-plane finisher (Table 1) throughout the experiment (d 0-91).
[2)]Fed the grower and high-plane finisher during d 0-38 and 38-84, respectively.
[3)]B, barrow; G, gilt; Final Data are means of 5 animals.
[4)]N, plane of nutrition; S, sex; BFT, backfat thickness; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids.
[5)]Average of the measurements between the 11 and 12th ribs and at the last rib adjusted for a 125-kg live weight.

LPN group than in the HPN group (9.50 vs. 8.01) whereas the b* value of backfat covering the LM was greater in the latter. The pHu was greater in the LPN vs. HPN group, but the pH values of both groups were within the normal range of 5.0-6.0 of the RFN (reddish-pink, firm, and non-exudative) pork (Warner *et al*., 1997). Drip loss, which was not influenced by the treatment or sex, was greater in gilts vs. barrows on the LPN, but not on HPN. The shear force for the LM was less in the LPN group than in the HPN group (3.23 vs. 5.68 kg/cm^2). Regarding the sex effect, none of the physicochemical characteristics described so far differed between gilts and barrows.

The content of moisture in the loin LM was greater in gilts than in the barrows whereas protein and fat contents of the muscle did not differ between the sexes. However, none of moisture, protein and fat contents differed between the treatments. In composition of fatty acids, none of the percentages of stearic acid (18:0), oleic acid (18:1), linoleic acid (18:2), and arachidonic acid (20:4) differed between the treatments or sexes. The ratios of total saturated fatty acids, polyunsaturated fatty acids, and n-3 fatty acids also were not influenced by the treatment or sex, except for a greater percentage of n-3 fatty acids in the gilt vs. barrow on the LPN, but not on HPN. In cooked LM, none of cooking loss, shear force, firmness, and chewiness was affected by the treatment or sex.

In fresh LM from Boston butt, the L* value as well as drip loss did not differ between the treatments or sexes (Table 4). The a* value and pHu of this LM were greater in the LPN vs. HPN group as in fresh loin LM, whereas shear force was less in the former ($p<0.01$). The fat content of this muscle did not differ between the treatments or sexes. In fresh SM, the LPN group exhibited a greater L* value than the HPN group [48.7 vs. 45.0 ($p<0.01$)]. The a* value, pHu, and drip loss of the SM were not affected by the treatment or sex. Shear force for the SM, as in the LM, was less in the LPN vs. HPN group whereas fat content was greater in the HPN vs. LPN group (1.44 vs. 1.01%; $p<0.05$).

Sensory evaluation of meat quality

None of the color, marbling, off-odor, drip, and overall acceptability scores for fresh loin LM differed between the LPN and HPN groups or between barrows and gilts, except for a greater acceptability score for the barrow vs. gilt on the LPN, but not on HPN (Table 5). In fresh LM from Boston butt, the off-odor score was greater in the LPN vs. HPN group, otherwise, neither of the treatment and sex effects was detected in any other sensory quality trait. The fresh SM of the LPN group exhibited greater marbling and off-odor scores than the HPN group, but color, drip and overall acceptability scores for this muscle were not influenced by the treatment or sex. In sensory evaluation for cooked loin LM, the color score was

Table 4. Physicochemical characteristics of the muscle of the fresh ham and Boston butt in finishing pigs which were placed on either the low or high plane of nutrition

Variable	Low plane[1)]		High plane[2)]		SEM	*P*-value		
	B[3)]	G[3)]	B[3)]	G[3)]		N[4)]	S[4)]	N×S
				Longissimus muscle from Boston butt				
Color								
CIE L*	49.4	49.0	49.5	47.7	1.2	0.64	0.36	0.56
CIE a*	20.6	22.1	19.1	18.3	0.8	<0.01	0.70	0.19
pHu	6.16	6.25	5.70	5.83	0.09	<0.01	0.27	0.82
Drip loss (%)	1.03	0.97	0.70	1.28	0.32	0.97	0.44	0.34
Shear force (kg/cm^2)	1.95	2.77	4.51	4.05	0.38	<0.01	0.64	0.11
Crude fat (%)	3.43	2.32	4.29	3.48	0.61	0.12	0.14	0.81
				Semimembranosus muscle of the ham				
Color								
CIE L*	47.9	49.6	45.3	44.6	1.3	<0.01	0.70	0.35
CIE a*	15.12	13.54	12.64	13.80	0.72	0.14	0.77	0.07
pHu	6.20	6.21	6.00	5.96	0.11	0.06	0.86	0.85
Drip loss (%)	1.19	1.17	0.87	1.21	0.17	0.43	0.34	0.30
Shear force (kg/cm^2)	2.92	3.09	5.56	5.88	0.38	<0.01	0.53	0.85
Crude fat (%)	1.14	0.88	1.48	1.40	0.15	0.02	0.28	0.55

[1)]Fed the low-plane finisher (Table 1) throughout the experiment (d 0-91).
[2)]Fed the grower and high-plane finisher during d 0-38 and 38-84, respectively.
[3)]B, barrow; G, gilt. Data are means of 5 animals.
[4)]N, plane of nutrition; S, sex.

Table 5. Sensory meat quality traits of finishing pigs which were placed on either the low or high plane of nutrition[1)]

Variable	Low plane[2)]		High plane[3)]		SEM	P-value		
	B[4)]	G[4)]	B[4)]	G[4)]		N[5)]	S[5)]	N×S
Fresh longissimus muscle from the loin								
Color	7.78	7.50	7.18	7.35	0.21	0.09	0.78	0.30
Marbling	8.02	7.38	7.40	7.65	0.21	0.42	0.38	0.05
Off-odor	8.00	7.97	7.85	7.97	0.04	0.08	0.32	0.08
Drip	7.65	7.33	7.62	7.78	0.24	0.40	0.76	0.33
Acceptability	7.97	7.52	7.40	7.68	0.15	0.20	0.58	0.03
Fresh longissimus muscle from Boston butt								
Color	8.27	7.83	7.88	7.82	0.16	0.24	0.14	0.27
Marbling	8.08	7.87	7.92	7.67	0.19	0.35	0.23	0.93
Off-odor	8.08	8.08	7.92	7.93	0.05	0.01	0.87	0.87
Drip	8.35	7.97	7.82	7.68	0.23	0.09	0.27	0.59
Acceptability	8.08	7.90	7.83	7.68	0.17	0.18	0.33	0.92
Fresh semimembranosus muscle of the ham								
Color	7.90	7.33	7.70	7.73	0.16	0.54	0.11	0.08
Marbling	7.90	7.52	7.32	7.18	0.17	0.01	0.14	0.46
Off-odor	8.03	7.97	7.87	7.78	0.07	0.03	0.31	0.91
Drip	7.90	7.48	7.73	7.77	0.15	0.70	0.21	0.15
Acceptability	7.87	7.45	7.63	7.65	0.14	0.91	0.18	0.15
Cooked longissimus muscle from the loin								
Color	7.57	7.65	8.13	8.00	0.19	0.03	0.90	0.57
Aroma	7.38	7.63	7.23	7.37	0.15	0.20	0.23	0.71
Taste	7.35	7.70	7.35	7.48	0.16	0.50	0.14	0.50
Juiciness	7.28	7.27	7.18	7.53	0.11	0.48	0.17	0.13
Tenderness	7.70	7.28	7.30	7.33	0.15	0.27	0.23	0.16
Palatability	7.40	7.62	7.38	7.58	0.17	0.89	0.24	0.96

1)Evaluated by six panelists according to an arbitrary 1-to-9 whole-number point scale. A greater score indicates a greater quality in all quality traits. A greater score in off-flavor or drip therefore indicates a lesser extent of the corresponding trait.
2)Fed the low-plane finisher (Table 1) throughout the experiment (d 0-91).
3)Fed the grower and high-plane finisher during d 0-38 and 38-84, respectively.
4)B, barrow; G, gilt; Data are means of 5 animals.
5)N, plane of nutrition; S, sex.

greater in the HPN vs. LPN group. However, neither the treatment nor sex exhibited any significant effect on aroma, taste, juiciness, tenderness, or palatability.

Discussion

The use of LPN for the finishing pigs resulted in a 12.6% decrease in ADG without significantly influencing backfat thickness when compared with growth performance of the pigs placed on HPN. These results for LPN were similar to the effects for the low-energy diet in finishing pigs observed in previous studies (Ha *et al*., 2012; Lee *et al*., 2002; Park *et al*., 2009a).

Notably, the pigs placed on LPN exhibited higher pHu values in the loin and Boston butt LM than those on HPN. The pHu is known to increase when post-mortem glycolysis is insufficient due to a low muscular glycogen store at slaughter resulting from glycogenolysis-inducing pre-slaughter stresses, a low availability of dietary carbohydrates prior to slaughter, or others (Bee *et al*., 2006; Huff-Lonergan *et al*., 2003). In this context, it is tempting to speculate that a lower ratio of the carbohydrate-rich grains in the LPN vs. HPN diet (58.7% vs. 70.1%; data not shown), as well as a reduced anabolic status in the LPN vs. HPN group as indicated by a much lower ADG in the former during d 69-84/91, could have resulted in a lesser muscular glycogen store in the former. It is not known, however, whether or not the high pH greater than 6.0, a known cause of DFD (dark, firm, and dry) pork (Warner *et al*., 1997), due to LPN exerted any negative effect on the meat quality of the Boston butt LM and SM, although LPN did not cause a decrease in either the L* value below 42 typical of DFD or in the score for any of the quality traits including the color in sensory evaluation on the muscles.

The increased redness (a*) of fresh LM from both the loin and Boston butt in response to LPN vs. HPN, which was consistent with the effect for the low-energy diet on this attribute in finishing pigs (Park *et al*., 2009a), is thought to be a positive effect of LPN on meat quality, in that a redder color is perceived as better quality by consumers. The redness of the muscle is known to increase with the increase in its myoglobin content due to an increased slaughter age or Fe^{2+}:Fe^{3+} ratio of the prosthetic heme group within the myoglobin molecule following an increased muscular pH (Park, 2004). The increased redness of the LM in the LPN group vs. HPN is thus at least partly attributable to the 7-d older age at the time of slaughter and the higher pHu in the former.

The reduced shear force in the LPN vs. HPN group in all the fresh muscles examined is also thought to be a positive effect of the former on the quality of fresh meat. Moreover, the greater off-odor score in the LPN vs. HPN group in sensory evaluation for the fresh Boston butt LM and SM added to the beneficial effects of LPN on meat quality. On the other hand, the effect of LPN on the meat quality trait associated with intra-muscular fat was inconclusive, in that the greater fat content in the HPN vs. LPN group and the greater marbling score in the latter were contradictory to each other in the SM whereas in the loin and Boston butt LM, neither fat content nor marbling score was influenced by the plane of nutrition.

Collectively, the present results suggest that use of LPN for finishing pigs is effective for improving the quality of their meat to some extent when they are slaughtered at approximately 125 kg of body weight irrespective of the maximum allowance of carcass weight for the 1^+ carcass grade by the current grading standard [92.5 kg (121.7 kg of live weight at a dressing percentage of 76%); MAFRA, 2014]. This was consistent with the conclusion as to the effect of the low-energy diet containing 3,000 kcal DE/kg in finishing pigs in Park *et al*. (2009a). However, neither LPN nor the low dietary energy density (Park *et al*., 2009a) had any significant effect on overall quality of cooked meat evaluated by the sensory panel, although the color score was reduced by LPN in cooked LM in the present study. The positive changes in physicochemical and sensory quality attributes of fresh meat due to either dietary treatment therefore do not seem to be significant enough to influence the quality of cooked meat.

Apart from meat quality, the backfat thickness (BFT) adjusted for a 125-kg live weight of the pigs raised on LPN was 24.0 mm, which is thought to be too high and also too close to 24.5 mm of the maximum allowance for the 1^+-grade carcass (MAFRA, 2014). This is much greater than 21. 4 mm of BFT at the same live weight in the low-energy diet-fed high-lean pigs (Park *et al*., 2009a), in which the retrospectively assessed optimum slaughter weight for superior carcass and meat quality is 128±5 kg on the criteria that the optimum BFT is 22±1 mm (Park, 2011; Park *et al*., 2013a; MAFRA, 2014) and that the BFT increases at a rate of 0.20 to 0.25 mm/kg live weight (Jeong *et al*., 2010; Park and Lee, 2011; Park *et al*., 2013b). If the same criteria are adopted for the present pigs endowed with a medium lean gain potential, the optimum slaughter weight is assessed to be 116±4 kg. It remains unknown, though, whether or not the meat quality of the pigs will be improved by LPN when they are slaughtered at the predicted optimum weight.

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