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Feasibility of Increasing the Slaughter Weight of Finishing Pigs

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ABSTRACT

The present review was aimed to assess the feasibility of increasing the slaughter weight (SW) of finishing pigs. Growth performance, including ADG, ADFI and gain:feed, does not change significantly with increasing SW between 110 and 135±5 kg in lean-genotype pigs, whereas in non-lean pigs, ADG and gain:feed decrease with increasing SW within the similar range of BW. Backfat thickness (BFT) and marbling of the carcass, which are greater in barrows than in gilts, increase with the increase of SW. The SW could be increased by using a low-energy diet and thereby reducing the rate of fat deposition per weight gain. The yield of the belly increases with the increase of SW, which may be economically significant in Korea. However, yields of some other primal cuts do not change so much as to affect the carcass value. The redness and fat content of the muscle increase slightly with the increase of SW whereas moisture content is minimally influenced by SW. Muscular protein content rarely changes, but sometimes increases slightly, with increasing SW. Other physicochemical characteristics, including lightness, pH, drip loss, and cooking loss of the muscle, are barely influenced by SW. Marbling of fresh loin and ham increases with increasing SW. Sensory characteristics of fresh loin, ham, and belly, including color, aroma, off-flavor, drip, and acceptability, are not influenced significantly by SW. The eating quality of cooked pork also has almost no relation to SW. In conclusion, it is thought that the current SW for moderately lean barrows and gilts can be raised up to 125 and 135 kg, respectively, with BFT at these weights predicted to be approximately 24 mm near the last rib, without compromising the meat quality.

(**Key words :** Finishing pig, Growth, Slaughter weight, Carcass, Meat quality)

INTRODUCTION

The slaughter weight (SW) of finishing pigs is an important economic variable which affects not only the meat quality but also the profitability of pig production (Kim et al., 2005; Bonneau and Lebret, 2010). In general, it is beneficial to the producer to increase SW because following the increase of SW, total number of animals required to produce a given weight of pork is reduced, normally accompanied by a reduced production cost. However, an increase of SW beyond a certain limit results in excessive fat deposition and the ensuing decrease in growth efficiency and carcass quality. Most modern pigs are therefore have been bred so leanly that the high lean gain potential of early finishing pigs does not decrease significantly up to SW which is now much greater than was possible a few decades ago.

The pig SW is influenced by a number of extrinsic factors as well. First of all, the consumers' preference for the fat content of pork influences SW to a most significant extent. In this regard, finishing pigs may well be slaughtered at higher BW in countries including Korea where the fatness of the carcass or primal cuts favored by the consumers is relatively high. However, the average SW in Korea is lower than those in the USA and some European countries where lean pork is preferred (DARD, 2002; MLC, 2003; Kim et al., 2009; Table 1). The SW is also influenced by traditional as well as cultural backgrounds. For instance, in Hawaii where a high percentage of pig carcasses are used for barbecuing, the average SW is only approximately 90 kg (NASS, 2006) whereas in some Mediterranean regions where dry-cured ham and other pork products requiring large carcasses are produced, pigs are slaughtered at approximately 160 kg (Kim et al., 2005; Bonneau and Lebret, 2010). In addition, SW is widely variable depending on the carcass size that is desired by the butcher or packer, as is exemplified by the variations of average SW in the different states of the USA, which range approximately from 90 to 140 kg (NASS, 2006).

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Table 1. Average market weights of finishing pigs in selected countries in 2007 (from Kim et al., 2009)

Country	Market Weight (kg)	Country	Market Weight (kg)
Denmark	108.5	Canada	113.00
Netherlands	111.50	U.K.	98.80
France	115.80	U.S.A.	120.15
Republic of Ireland	98.40	Japan	114.00
Germany	120.00	Korea	111.1

began the studies on the present topic with a review (Kim et al., 2005) covering the world trend of the pig market weight, the expected changes of the carcass and meat quality resulting from an increase of SW, and the nutritional and hormonal methods by which SW can be increased. This was followed by serial studies on various effects of increasing SW up to 138 kg (Lee et al., 2006, 2007; Park et al., 2007, 2009a,b). The main results of these studies have been pooled and analyzed in a previous study (Jeong et al., 2010) to render regressive relationships of SW to the variables associated with growth efficiency and physicochemical and sensory characteristics of major primal cuts.

The present study was undertaken to review the literature on the relationships between dietary energy level and growth efficiency of finishing pigs in association with their lean-gain potential and SW and thereby to assess the feasibility of increasing SW. The present review was also aimed to further analyze published results regarding the effects of SW of swine on their growth efficiency and physicochemical and sensory characteristics of fresh and cooked primal cuts of their resulting carcasses.

RELATIONSHIPS BETWEEN SLAUGHTER WEIGHT AND PRODUCTION EFFICIENCY OF FINISHING PIGS

1. Growth efficiency

The average daily gain (ADG) is usually greater in barrows than in gilts (Latorre et al., 2009; Table 2). The ADG barely changes with increasing SW between 110 and 135±5 kg in lean-genotype finishing pigs (Neely et al., 1979; Lee et al., 2006; Park et al., 2007, 2009b), although in a study of Latorre et al. (2008), ADG did not change up to 125 kg and declined thereafter. Furthermore, Cisneros et al. (1996) have reported that ADG of finishing pigs beginning from 60 kg had no relation to final BW between 100 and 160 kg. Similarly, in the study of Corino et al. (2008), ADG between 114 and 161kg BW (1.06 kg) was only marginally less than that between 78 and 111 kg (1.17 kg). In non-lean pigs, however, a negative effect of increasing BW on ADG is evident even at above 100 kg (Kanis et al., 1990; Latorre et al., 2004, presented in Table 3).

The average daily feed intake (ADFI), which is greater in barrows than in gilts, usually increases slightly with increasing BW (Cisneros et al., 1996; Piao et al., 2004; Park et al., 2009b) up to approximately 135 to 140 kg irrespective of the genotype for lean gain, although there are incidences where ADFI was not influenced by SW (Latorre et al., 2004, 2008). In contrast to this, the gain:feed ratio is inconsistently influenced by sex and SW. The gain:feed ratio of gilts was superior to that of barrows in the studies of Leach et al. (1996) and Latorre et al. (2004 Table 3), but in Latorre et al. (2009) and others (Table 2), it did not differ between the two sexes. Moreover, the gain:feed ratio decreased slightly with increasing SW between 110 and 140 kg in some studies (Latorre et al., 2004, presented in Table 3; Piao et al., 2004; Park et al., 2009a), whereas in others (Cisneros et al., 1996; Leach et al., 1996; Park et al., 2007, 2009b), it was not influenced by SW within the similar range of SW. Dressing percentage usually neither differs between the barrow and gilt nor changes with increasing SW (Piao et al., 2004; Lee et al., 2006; Park et al., 2009a,b). However, sometimes, it is slightly greater in gilts than in barrows (Latorre et al., 2004; Lee et al., 2007; Park et al., 2007) and also slightly increases with the increase of SW (Cisneros et al., 1996; Latorre et al., 2008).

In summary, growth performance of lean-genotype pigs including the ADG and gain:feed ratio usually does not change significantly with the increase of SW up to approximately 140 kg. In non-lean pigs, however, both ADG and gain:feed decrease with increasing SW above 100 kg.

2. Backfat thickness and slaughter weight

Backfat thickness (BFT) is greater in barrows than in gilts, which is partly associated with the greater ADFI in the barrow (Tables 2 and 3). This variable also increases linearly with increasing BW, with a slope of 0.18 to 0.24 mm/kg,

Table 2. Influences of slaughter weight (SW) on growth performance of lean-type finishing pigs[1)]

Item	Gilt		Barrow		SE	Sig.[a]	Regression on SW		
	Low SW	High SW	Low SW	High SW			Slope	SE	Sig.[a]
Initial wt, kg	85.8	87.0	86.2	86.9	0.6		–	–	–
Final wt, kg	109.2	132.0	110.2	127.3	0.6	S**, SW**	–	–	–
ADG, kg	0.79	0.84	0.89	0.89	0.02	S**	0.003	0.0007	**
ADFI, kg	3.12	3.45	3.33	3.52	0.05	S**, SW**	0.011	0.0022	**
Gain:feed	0.238	0.236	0.249	0.241	0.005		0.000	0.0002	
Backfat, mm	18.4	23.3	20.8	24.2	0.4	S*, SW**	0.217	0.0162	**
Carcass wt, kg	81.4	99.9	81.6	95.5	0.5	S**, SW**	0.787	0.0110	**
Dressing, %	74.5	75.7	74.1	75.0	0.2	S*, SW**	0.027	0.0081	**

[1)] Pooled data from a total of 480 (Yorkshire × Landrace) × Duroc finishing pigs used in three published studies (Lee et al., 2006; Park et al., 2007, 2009b) were analyzed using GLM of SAS (1996). The model included the separate experiment corresponding to the 'plot' of a split-plot design and the interactions associated with it, in addition to sex, SW, sex × SW and the linear effect of SW, as fixed errors. The low SW for gilts and barrows was 110 kg; the high SW were 130 to 138 kg for gilts and 125 or 130 kg for barrows, respectively. Backfat thickness is the average of the measurements between the 11th and 12th ribs and between the last rib and the 1st lumbar. All animals received a diet containing 3.2 Mcal DE/kg. For brevity, effects of the separate experiment and the interactions associated with it are not indicated in this table.

[a] S, sex; * P<0.05; ** P<0.01.

Table 3. Influences of slaughter weight on growth performance of non-lean finishing pigs[1)]

Item	Sex				Slaughter weight (kg)				
	Gilt	Barrow	SE	Sig.	116	124	133	SE	Sig.
Initial wt, kg	74.2	75.5	0.4	**	74.9	74.7	74.8	0.4	
Final wt, kg	120.9	128.5	1.1	**	116.2	124.4	133.5	1.3	**
ADG, kg	0.75	0.85	0.02	**	0.84	0.79	0.77	0.05	**
ADFI, kg	2.45	2.84	0.05	**	2.69	2.56	2.68	0.06	
Gain:feed	0.307	0.298	0.003	*	0.313	0.309	0.287	0.003	**
Backfat, mm	22.7	27.6	0.5	**	22.1	25.7	27.0	0.6	**
Carcass wt, kg	94.7	99.5	0.8	**	89.8	96.4	105.1	1.0	**
Dressing, %	78.3	77.4	0.2	**	77.3	77.7	78.6	0.2	**

[1)] Data, which were adapted from Latorre et al. (2004), are the means of 96 non-lean (Landrace × Yorkshire) × (Pietrain × Yorkshire) finishing pigs. Backfat thickness was measured between the 3rd and 4th last ribs.

* P<0.05; ** P<0.01.

depending on the genotype, feeding program, or location of the back where the BFT is measured (Gu et al., 1992; Cisneros et al., 1996; Latorre et al., 2004; Jeong et al., 2010).

The maximal SW is limited by the fat content of the body represented by BFT which increases linearly with increasing SW (Gu et al., 1992). If consumers should allow BFT up to 24 mm, the maximal SW for gilts and barrows assessed from the data presented in Table 2 are 135 and 126 kg, respectively. Now that the present assessment has been made using data from animals which received a 'medium' energy-dense finisher diet containing 3.2 Mcal DE/kg, the suggested maximal SW may need to be reset downward if a producer uses a diet containing 3.4 Mcal DE/kg recommended by NRC (1998) or a higher energy-dense diet. It also should be noted that in those countries where lean pork is preferred, restricted feeding or a low-energy diet may be needed to reach the suggested maximal SW without encountering with overfattening.

3. Influence of dietary energy level on growth

Upon increasing the dietary energy level between 2.9 and 3.5 Mcal DE/kg, ADG, gain:feed, and BFT usually increase while ADFI decreases (Chung et al., 1981; Chang and Chung, 1985; Lee et al., 2000, 2002). However, these effects of the dietary energy level are somewhat variable depending on the energy contents of the diets that are being compared. For instance, ADG and gain:feed were greater in lean-genotype finishing pigs which had received the medium-energy (3.2 Mcal DE/kg) vs 'low'-energy (3.0 Mcal DE/kg) diet (Park et al., 2009b), whereas in an earlier study (Lee et al., 2007), effects of a 'high'- (3.4 Mcal DE/kg) vs the medium-energy diet were non-significant in any of the growth variables including ADG and gain:feed (Table 4). Moreover, the effects of the low- vs medium-energy diet observed in the lean pigs were not significant in non-lean pigs in a later study (Ha et al., 2010).

Assuming that the BFT accretion rate of finishing pigs is 0.217 mm/kg BW and that pigs on the low-energy diet (3.0 Mcal DE/kg) vs the control (3.2 Mcal DE/kg) have 1.8-mm less BFT at slaughter as presented in Tables 2 and 4, pigs on the low-energy diet will need to gain 8 kg more to reach the BFT of the animals which receive the control diet. In other words, the SW at a fixed target BFT will be 8 kg greater in those pigs fed the low-energy vs control diet. Although this appears to be somewhat of an overassessment, it seems quite feasible to increase SW to some extent by virtue of the BFT-reducing effect of the low-energy diet. The SW could also be increased by restricted feeding which is known to be useful for reducing fat deposition and for increasing the gain:feed ratio, especially in finishing barrows (Leymaster and Mersmann, 1991), but this method does not seem to be as useful as the use of the low-energy diet in terms of practical applicability.

These results suggest that SW of finishing pigs could be increased by providing them with a low-energy diet containing a 3.0 Mcal DE/kg or less energy content vs a common diet containing 3.2 Mcal or greater DE per kg and thereby reducing the rate of fat deposition which limits the maximal SW. However, use of the low-energy diet will result in decreased ADG and gain:feed as well as decreased fat deposition.

Table 4. Effects of dietary energy level on growth performance of lean-type finishing pigs slaughtered at heavy weights

Item	Lee et al. (2007)						Adapted from Park et al. (2009b)				
	3.4 Mcal DE/kg		3.2 Mcal DE/kg		SE	Sig.[a]	3.2 Mcal DE/kg		3.0 Mcal DE/kg		SE
	Gilt	Barrow	Gilts	Barrow			Gilt	Barrow	Gilt	Barrow	
Initial wt[b], kg	93.0	89.7	93.6	90.2	0.9	S**	79.9	79.9	79.9	80.4	0.9
Final wt[b], kg	135.5	124.8	135.3	124.1	0.7	S*	135.0	125.6	138.5	127.9	0.8
ADG[b], kg	0.80	0.75	0.82	0.79	0.02		0.93	1.03	0.81	0.88	0.03
ADFI[c], kg	2.94	2.90	2.91	3.03	0.10		3.32	3.79	3.61	3.79	0.04
Gain:feed[c]	0.268	0.255	0.274	0.254	0.008		0.281	0.272	0.226	0.233	0.009
Backfat[b,d], mm	24.3	24.0	22.4	24.7	0.6	S×D*	25.9	24.6	22.0	22.9	1.0
Carcass wt[b], kg	102.3	92.9	101.3	92.6	0.6	S**	102.3	94.3	105.1	95.2	1.1
Dressing[b], %	75.5	74.5	74.9	74.6	0.3	S*	75.8	75.0	75.9	74.4	0.8

[a] S, sex; D, diet.
[b] Data are the means of 40 and 16 animals in each diet × sex combination in Lee et al. (2007) and Park et al. (2009b), respectively.
[c] Data are the means of four pens (replicates) in each diet × sex combination in both studies.
[d] Adjusted for a 125-kg live weight for barrows in both studies, and for 135- and 138-kg live weights for gilts in the studies of Lee et al. (2007) and Park et al. (2009b), respectively.
* $P<0.05$; ** $P<0.01$.

INFLUENCES OF SLAUGHTER WEIGHT ON CARCASS GRADES AND PRIMAL YIELDS

1. Carcass weight and grading

The carcass grading criteria in different countries are not only widely variable but are thought to be beyond the scope of present review. Accordingly, the current situation regarding the relationship between SW and the carcass grade in Korea will be introduced here as an example. Pig carcasses in Korea have been judged to A, B, C, or D of yield grade primarily according to BFT and carcass weight which should be between 80 and 94 kg to be eligible for grade A, and between 76 and 98 kg to be eligible for grade B (MIFAFF, 2007). If the maximum carcass weights for grades A and B are converted to live weights by dividing them by 0.75 of the average dressing ratio, they are equal to 125 and 131 kg live weights, respectively, which are close to the 126 and 135 kg maximal SW suggested for the barrow and gilt, respectively, in the previous section. The average SW in Korea, however, is only 111 kg (Table 1) for the following reasons. Most packers discount the price for any carcass weighing 90 kg or greater ($\geq$ 120 kg in live weight) regardless of the yield grade to assure the size uniformities of their wholesale cuts. What is more, they try to safeguard the quality of the belly, the most preferred and expensive cut in this country, by penalizing the larger carcasses and thereby minimizing the chance of 'adulterating' their wholesale packs with what they call the "caky-fat" belly which is found in some of the fat carcasses exhibiting a 30 mm or greater BFT. Consequently, many pig producers do not dare to increase the pig market weights to the maximum for fear of the oversize penalty, which results in the average SW being lower than is desirable. Therefore, to be fair to the producers, it is thought to be necessary to raise the maximum carcass weights for good grades accepted by the packer as well as for yield grades A and B.

2. Carcass quality

The BFT and marbling score are probably the most representative carcass grading criteria throughout the world. These two carcass quality variables, which are greater in barrows than in gilts, are correlated although the coefficient is not significant in gilts (Table 5). Moreover, in the study of Park et al. (2009b), marbling at 138 kg of live weight increased when a 9-week finishing period on the control diet (3.2 Mcal DE/kg) was extended by approximately one week by using the low-energy diet (3.0 Mcal DE/kg). This is consistent with the notion that marbling increases not only with adipose tissue growth but also with age (Huff-Lonergan et al., 2003). Interestingly, carcass quality grade was highly correlated with marbling as well as with BFT to some extent when the grade was quantified. Marbling therefore appears to

Table 5. Backfat thickness (BFT), marbling grade (MG), and quality grade (QG) of pig carcasses: effects of sex and Pearson's correlations between liveweight (LW), BFT, MG, and QG[1)]

Item	Mean ± SD			Pearson's correlation coefficient with the corresponding variable								
	Gilts (n=168)	Barrows (n=168)	Sig.	Within Gilts			Within Barrows			Gilts + Barrows		
				BFT	MG	QG	BFT	MG	QG	BFT	MG	QG
LW, kg	120.3±10.7	120.7±12.0		0.48**	0.02	0.04	0.26**	−0.06	0.03	0.34**	−0.02	0.04
BFT, mm	21.1± 4.1	23.9± 4.8	**	−	0.05	0.05	−	0.24**	0.18*	−	0.23**	0.19**
MG[a]	1.74± 0.63	2.16± 0.85	**	−	−	0.64**	−	−	0.70**	−	−	0.69**
QG[b]	2.61± 0.56	2.90± 0.58	**	−	−	−	−	−	−	−	−	−

[1)] Pooled data from three studies (Park et al., 2009b; Ha et al., 2010; unpublished results of C. Y. Lee et al.) were analyzed using GLM Procedure and CORR Procedure of SAS (1996). In the first study, a total of 192 pigs were slaughtered at 110, 125, or 138 kg, with equal numbers of gilts and barrows assigned at each target weight; in the latter two studies, 72 gilts and 72 barrows in total were slaughtered approximately at 115 kg. The GLM included the separate study and sex as well as their interaction, but for brevity, effects of the separate study and the interaction are not indicated in this table.

[a] No. 4 or 5, No. 2 or 3, and No. 1 of the MIFAFF (2007) standard corresponding to the quality grades 1^+ & 1, 2, and 3 were assigned 4, 2, and 1 points of an arbitrary grade unit, respectively.

[b] Judged according to the quality of the whole carcass including the meat color, texture, marbling, quality of fat including its color, and the quality of the belly which includes the absolute and relative thicknesses (balance) of the fat and muscle layers (MIFAFF, 2007). Grades 1^+, 1, 2, and 3 were assigned 4, 3, 2, and 1 points of an arbitrary grade unit, respectively.

* P<0.05; ** P<0.01.

be a most significant factor determining the quality grade of pig carcasses in Korea.

3. Primal yield

The yield percentage of total trimmed primal cuts per SW is usually greater in gilts than in barrows and also in the high-lean vs medium- or low-lean genotype due to a greater percentage of trimmed subcutaneous fat in the latter (Martin et al, 1980; Unruh et al., 1996; Park et al., 2007; Latorre et al., 2008; Table 6). However, published results on the effect of SW on this variable are inconsistent. Martin et al. (1980) and Corino et al. (2008) have reported that the primal yield percentage decreased with increasing SW, whereas in Neely et al. (1979) and Park et al. (2007), SW exerted no influence on this variable.

Yields of some primal cuts other than the belly are influenced by SW within such narrow ranges (Cisneros et al., 1996; Latorre et al., 2004, 2008; Jeong et al., 2010) as not to influence the carcass value. However, the yield of the belly increases by 0.35 to 0.5% per 10 kg increase of SW (Martin et al., 1980; Jeong et al., 2010).

In summary, marbling of finishing pigs can be enhanced by providing them with a low-energy diet and thereby extending the age at a pre-determined slaughter weight. The yield percentage of the belly increases linearly with increasing SW up to 140 kg, which is considered to be economically significant in Korea. However, percent yields of some other primal cuts are minimally influenced by SW not only numerically but economically.

PHYSICOCHEMICAL CHARACTERISCTICS OF THE MUSCLE

1. Physical attributes

The size of all types of muscle fibers, i.e. Types I (red), IIB (white), and IIA (intermediate), in the loin increases with increasing SW of finishing pigs between 110 and 140 kg (Park, 2010). On the other hand, the density of these muscle fiber types per mm^2 cross-section decreases almost proportionately (Ryu and Kim, 2005; Park, 2010).

The lightness [CIE (1978) L*] of the longissimus muscle (loin), ham, and belly neither differs between gilts and barrows nor changes with increasing SW to any significant extent (Corino et al., 2008; Jeonget al., 2010; Table 7). The redness (a*) of these cuts is not influenced by the gender. Instead, the a* value, which reflects the muscular myoglobin

Table 6. Effects of slaughter weight (SW) on the yields of primal cuts of finishing pigs (adapted from Leach et al., 1996)

Item	Barrow[a]	Gilt[a]	SE	Sig.[b]	Linear regression on SW		
					Slope	SE	Sig.[b]
Live weight, kg	121.8	121.5	0.51	NS	—	—	—
Side wt (trimmed), kg	42.3	44.9	0.51	***	−0.097	0.0383	Bar[c]
					−0.000	0.0468	Gilt[c]
Wholesale cut percentage							
Ham	25.4	26.7	0.24	***	−0.019	0.0159	NS
Loin	26.7	26.1	0.31	NS	−0.038	0.0200	NS
Belly	16.0	15.4	0.32	NS	−0.002	0.0272	Bar[c]
					0.092	0.0237	Gilt[c]
Spare ribs	3.3	3.4	0.08	NS	0.005	0.0051	NS
Shoulder	20.6	20.4	0.21	NS	0.008	0.0139	NS
Clear plate	2.6	2.0	0.09	***	0.004	0.0057	NS
Jowl	3.4	3.4	0.13	NS	0.003	0.0087	NS

[a] A total of 144 pigs were slaughtered at 110, 125, or 140 kg, with equal numbers of gilts and barrows assigned at each live weight.
[b] NS, non-significant; *** P<0.001.
[c] Regressions differ (P<0.05) for barrow (Bar) and gilt.

content, increases with the increase of SW (Latorre et al., 2004; Park et al., 2007) concomitantly with the developmental increase of the myoglobin content (Martin et al., 1980; Latorre et al., 2004 Corino et al., 2008). There are incidences, however, where an increase of the a* value associated with growth does not reach a statistical significance (Leach et al., 1996; Table 7).

The 24-h muscular pH does not change or slightly decreases with the increase of SW (Corino et al., 2008; Park et al., 2009a,b), with an exception of a slight increase of loin pH with the increase of SW in Park et al. (2009a). However, the change in pH unit associated with the increase of SW within a practical range is not large enough to increase the incidence of PSE (pale, soft, and exudative) which can be caused by low *postmortem* muscular pH (Cisneros et al., 1996).

Drip losses of the loin and ham are circumstantially influenced slightly by the sex or SW. However, the effects of the sex and SW on this attribute within the practical range are thought not to be significant enough to affect the incidence of PSE which also occurs at a 5% or greater drip loss (Warner et al., 1997; Joo et al., 1999). Cooking losses of the lean cuts are quite variable among published results in terms of numerical measurements as well as with respect to the effects of the gender and SW (Latorre et al., 2004; Park et al., 2009b).

2. Chemical composition

The moisture content in the loin, ham and belly is minimally influenced by the gender or SW. Sometimes, the moisture content in these cuts neither differ between the two sexes nor changes with increasing SW, but at other times, it is slightly greater in gilts than in barrows and also increases slightly with increase of SW (Cinseros et al., 1996; Latorre et al., 2004, 2009; Fernandez-Duenas et al., 2008; Table 7).

Table 7. Physicochemical characteristics of the longissimus muscle of lean-type finishing pigs: effects of sex and regressions on slaughter weight (SW)

Item	Sex		Target SW		SE	Sig.[a]	Linear regression on SW		
	Gilt	Barrow	Low	High			Slope	SE	Sig.[a]
Live weight[1)]	120.2	118.5	109.2	129.5	0.9	W**	−	−	−
Muscle color[1)]									
CIE L*	51.3	52.4	52.2	51.5	0.6		−	−	−
CIE a*	7.28	7.27	7.14	7.41	0.27		−	−	−
Chemical composition[1)], %									
Moisture	74.0	73.9	74.0	73.9	0.2		−	−	−
Protein	22.4	22.2	22.0	22.5	0.1	W**	−	−	−
Live weight[2)]	127.7	127.9	−	−	3.5		−	−	−
pH-24 h[2)]	5.67	5.65	−	−	0.03		−0.002	0.0010	S
Drip loss[2)], %	3.36	3.26	−	−	0.32		0.029	0.0106	S
Cooking loss[2)], %	23.36	23.35	−	−	0.70		0.018	0.0229	NS
Chemical composition[2)], %									
Moisture	73.14	72.85	−	−	0.16		−0.035	0.0053	S
Fat	3.26	3.70	−	−	0.19		0.027	0.0061	S

1) Pooled data for a total of 152 loins derived from as many (Yorkshire × Landrace) × Duroc finishing pigs used in three published studies (Lee et al., 2006; Park et al., 2007, 2009b) were analyzed using GLM of SAS (1996). The model included the separate experiment corresponding to a 'plot' of a split-plot design and the interactions associated with it, in addition to sex, SW, sex × SW and the linear effect of SW, as fixed errors. The slaughter weights ranged from 110 to 138 kg. For brevity, effects of the separate experiment and the interactions associated with it are not indicated in this table.

2) Data were adapted from the paper of Cisneros et al. (1996) in which 40 commercial hybrid and 40 (Yorkshire × Landrace) × Hampshire pigs were slaughtered at 100, 115, 130, 145, or 160 kg.

a W, target SW; ** P<0.01; S, significant (P<0.05); NS, non-significant (P>0.05).

The protein content of the loin and ham is sometimes slightly greater in gilts than in barrows; at other times, however, it does not differ between the two sexes (Latorre et al., 2004; Wiseman et al., 2007; Park et al., 2009a,b; Table 7). Muscular protein content usually is not affected significantly by SW within a given genotype (Unruh et al., 1996; Latorre

Table 8. Sensory quality characteristics of fresh and cooked pig loin and belly: effects of sex and slaughter weight (SW)[1)]

Item	Gilt			Barrow			SE	Significance
	Low SW	Medium SW	High SW	Low SW	Medium SW	High SW		
Live wt, kg	107.5	124.9	136.8	110.4	126.8	139.6	0.6	SW**
Fresh meat								
Loin								
Color	5.59	5.94	5.60	5.52	5.82	5.45	0.24	
Aroma	3.14	3.09	3.13	3.23	3.19	2.98	0.10	
Off-flavor	2.54	2.36	2.29	2.46	2.33	2.42	0.07	SW*
Drip	5.12	5.20	5.25	5.41	4.90	4.97	0.20	
Marbling	3.70	4.74	4.70	4.31	5.07	5.28	0.36	SW*
Acceptability	4.99	5.36	5.30	5.23	5.45	5.46	0.16	
Belly								
Color (fat)	5.24	4.88	5.26	5.32	5.44	5.32	0.18	
Color (muscle)	5.38	5.69	5.90	5.68	5.67	5.98	0.16	SW*
Aroma	3.54	3.71	3.74	3.74	3.73	3.79	0.10	
Off-flavor	1.87	1.31	0.76	0.77	1.35	1.42	0.32	
Fat:lean ratio	4.61	5.01	5.26	5.13	6.18	5.90	0.24	Sex**, SW**
Fat:lean balance	4.82	5.39	5.06	5.17	5.00	5.05	0.15	
Acceptability	5.00	5.57	5.35	5.18	5.18	5.42	0.16	
Cooked meat								
Loin								
Color	5.13	5.16	5.08	4.98	5.04	5.20	0.15	
Aroma	3.54	3.59	3.72	3.69	3.66	3.69	0.11	
Off-flavor	2.71	2.73	2.74	2.54	2.67	2.84	0.10	
Juiciness	4.45	4.32	4.29	4.16	4.39	4.44	0.20	
Tenderness	4.96	5.05	4.87	5.14	5.20	5.25	0.23	
Acceptability	5.16	5.35	5.05	5.31	5.30	5.35	0.17	
Belly								
Aroma	4.68	4.56	4.78	4.63	4.71	4.66	0.13	
Off-flavor	2.47	2.48	2.52	2.48	2.51	2.51	0.09	
Juiciness	5.43	5.37	5.48	5.51	5.46	5.53	0.11	
Tenderness	5.50	5.67	5.71	5.63	5.86	5.51	0.15	
Taste	5.85	5.65	5.81	5.62	5.70	5.85	0.14	
Acceptability	5.50	5.53	5.62	5.60	5.63	5.53	0.13	

[1)] Data were adapted from a previous study (Park et al., 2009b). Quality traits were judged by sensory panelists according to a 9-point hedonic scale. Greater values indicate “darker,” “stronger,” “superior,” and “greater” in color, aroma, fat:lean balance/acceptability, and fat:lean ratio/marbling, respectively. In off-flavor and drip, a greater value indicates “more” meaning “worse” in terms of quality. Data are means of 12 animals in each sex × SW combination.

* $P<0.05$; ** $P<0.01$.

et al., 2004); however, the protein content in the loin sometimes increases with increasing SW in lean-type pigs (Piao et al., 2004; Table 7).

Fat contents of the loin and belly are greater in barrows than in gilts and normally increase with increasing SW (Jeong et al., 2010; Table 7), which is in line with the effects of the gender and SW on the fatness of the body. Moreover, Wiseman et al. (2007) and Schinckel et al. (2008) have reported that muscles of a high-lean genetic line (375 gm fat-free lean gain/day) had greater growth rates and greater contents of protein and moisture, lesser daily fat gain, and lesser fat content than those of a low-lean genetic line (280 gm fat-free lean gain/day). In the studies of the present author's team, the fat content of the ham was not influenced by sex or SW (Park et al., 2009a,b), whereas the composition of fatty acids of the loin was not consistent [Lee et al., 2006; Park et al., 2007; Park et al., 2009a,b (unreported therein)].

Collectively, the redness and fat content of the muscle increase slightly with the increase of SW. However, other physicochemical characteristics, as well as the histological characteristics, of the muscle do not change so much as to influence meat quality

SENSORY QUALITY TRAITS OF FRESH AND COOKED MEAT

1. Fresh meat

Meat color, aroma, off-flavor, and drip of fresh loin and ham judged by sensory panelists are uninfluenced or minimally influenced by sex or SW (Park et al., 2007, 2009a,b; Table 8). However, the increase of marbling of these cuts occurring with increasing SW is considered to be significant in terms of meat quality. The acceptability for these cuts does not change or increases to some extent with the increase of SW between 110 and 125 kg. Collectively, the meat quality of fresh loin and ham does not change or improves slightly with increasing SW up to 125 kg.

Fat and muscle color, aroma, and off-flavor of fresh belly may differ statistically between gilts and barrows or at different SW (Park et al., 2007, 2009a,b; Table 8), but such effects of the sex and SW are thought to be insignificant in terms of meat quality. The fat:lean ratio of the loin, referring to the relative area of total fat layers vs total muscle layers, is greater (Table 8) or tends to be greater (Jeong et al., 2010) in barrows than in gilts, which is consistent with the relative fatness of the former vs latter. Similarly, this variable increases visibly between 110 and 125 kg of SW, although it does not increase further between 125 and 138 kg (Park et al., 2009a). The fat:lean balance of the loin, which is a measure for the appropriateness of the overall fatness of this primal, is an important quality criterion for this primal in Korea. This quality trait is not usually influenced by either sex or SW (Park et al., 2007, 2009a,b), but in the 2009a study of the workers, it improved significantly with the increase of SW between 110 and 125 kg, but not between 125 and 138 kg. The acceptability for this cut, however, was not affected by SW in any of the studies. Taken together, in Korea, the quality of fresh belly may or may not improve to some extent with the increase of SW up to 125.

2. Cooked pork

Sensory characteristics of cooked loin and ham, including color, aroma, off-flavor, juiciness, and acceptability, are barely influenced by sex or SW in lean-type pigs (Cisneros et al., 1996; Leach et al., 1996; Kim et al., 2006; Jeong et al., 2010; Table 8). The tenderness of the loin was negatively correlated with SW with a low slope in Cisneros et al. (1996) among these studies, but this is partly attributable to a greater range of SW in this study (100 to 160 kg) vs the others (110 to 138 or 140 kg; Leach et al., 1996; Table 8). Sensory characteristics including taste of cooked belly, like those of cooked loin and ham, are uninfluenced by sex or SW. It is therefore apparent from these results that the eating quality of cooked pork is virtually uninfluenced by sex or SW.

CONCLUSIONS

An increase of the pig SW up to 140 kg does not cause any adverse effects on growth efficiency in lean-genotype finishers, but not in non-lean ones. Irrespective of the genotype for lean gain, the primary limiting factor in increasing SW is the carcass grading standard with respect to the carcass weight and fat content. In this regard, SW could be increased to some extent by using a low-energy diet and thereby reducing fat deposition. The redness and marbling of the muscle usually increase with increasing SW, which could result in an improvement of meat quality; other physicochemical and sensory characteristics of trimmed primal cuts are barely influenced by SW. Sensory quality traits or the eating quality of cooked pork also does not change with the increase of SW. As such, in some regions or countries including Korea, it is possible that the SW for lean pigs be lower than desirable because of the carcass grading criteria. If this is the case, the upper limits of the carcass weights imposed on higher yield grades may well be adjusted upward to fully take advantage of the high production efficiency of the lean-type finisher at higher BW.

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