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Comparison of pork belly characteristics and weights of primal cuts between gilt and barrow of Landrace × Yorkshire × Duroc pigs measured by AutoFomIII

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Abstract

Currently, pigs breed in Korea are LYD (Landrace × Yorkshire × Duroc) crossbred pigs. Pigs used as fresh meat are gilts and barrows. However, the current supply of pork is not satisfying Korean consumers. In addition, the comparison of carcasses between gilts and barrows only studies carcass weight, backfat thickness, or meat quality, and there are very few studies comparing carcass characteristics. The purpose of this study was to compare characteristics of 7 primal cuts of gilts and barrows as measured by AutoFom III. A total of 350,179 pigs were used, including 176,461 gilts and 173,718 barrows. Characteristics of seven primal cuts were measured using AutoFom III. In the case of carcass weight, there was no significant difference in grade 1+. For all other survey items except for grade 2, gilts showed significantly ($p < 0.05$) higher values. For all grades except for pork belly, amounts of the remaining six primal cuts were higher in gilts (all $p < 0.05$,). In addition, the ratio of intermuscular fat in the pork belly of barrows showed a higher value than that in the pork belly of gilts ($p < 0.05$). The amount of pork belly, which is the most popular among consumers in Korea, not only produced more production than gilts in barrows, but also showed a higher value than gilts in barrows for the ratio of intermuscular fat affecting taste. In summary, gilts produced higher yields than barrows in all parts except pork belly. For the production of only pork belly, barrows showed higher production than gilts.

Keywords: Landrace × Yorkshire × Duroc (LYD), Gilt, Barrow, Grade, Belly, AutoFom III

INTRODUCTION

Currently, the most popular finishing pig in Korea is Landrace × Yorkshire × Duroc (LYD) species, a three-way crossbred of Landrace, Yorkshire, and Duroc. This LYD species created as a three-way crossbred has advantages of the three species by crossing a Landrace species with a high fertility

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No potential conflict of interest relevant to this article was reported.

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Ko E, Park Y, Kim J.
Data curation: Ko E, Woo C, Choi J.
Formal analysis: Park Y, Kim J.
Methodology: Park Y, Kim J.
Software: Park Y.
Validation: Park K, Woo C.
Investigation: Ko E, Woo C, Kim K.
Writing - original draft: Park Y.
Writing - review & editing: Ko E, Park Y, Park K, Woo C, Kim J, Kim K, Choi J.

Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

number, a fast-growing Yorkshire species, and a Duroc species with a high meat yield [1,2]. Among LYD species produced in this way, gilts and barrows are used as meat [3]. Barrows refer to boars that have been surgically castrated at a young age. Castration is performed because it lowers levels of androsterone and skatole in the meat. Androsterone and skatole are the main causes of boar odor. They can cause an unpleasant taste and odor in the meat of boars. Because of this, male piglets are usually surgically castrated within the first week of life to reduce boar taint and aggressive behavior and to eliminate sexual behavior [4,5].

In Korea, grilling pork is the most popular culture. Cuts such as pork belly and Boston butt with high fat are popular, whereas cuts such as hams and loin with low fat are less popular. Therefore, there is a large difference in the price of primal cut of pork in Korea [6]. Among pork cuts with high fat, pork belly is one of the most preferred cuts [7]. Since fat in the pork belly can enhance the flavor and juiciness of the meat [8], it is related to meat quality [9]. Pork belly accounts for about 13%–18% of pig carcass weight [10]. The supply of pork belly is important in Korea. However, the supply of pork belly could not satisfy Korean consumers [6]. Also, since the amount of pork belly can only be known after the pig carcass grade is evaluated, the amount of pork belly cannot be known immediately [11].

Since the income of Korean people is increasing, the per capita meat consumption is also increasing. In 2018, out of 53.9 kg of meat consumption per capita in Korea, the amount of pork was 27 kg, accounting for more than 50% of all meat consumption [12]. At the same time, the number of pigs slaughtered in Korea increased from 15 million in 2014 to 17 million in 2018 [13]. As so many pigs are slaughtered, an automatic grading machine is needed in the slaughterhouse. AutoFom III (Frontmatec Somerum A/S, Smørum, Denmark) is one of automatic grading machines using ultrasound. AutoFom III is currently used in slaughterhouses in 14 overseas countries including North America and Europe. AutoFom III showed very high accuracy that predicting the amount of pork belly and ham of pig carcass, regression coefficients were respectively 0.98, 0.93 [14]. Also Choi et al. [15] indicated that the prediction accuracy was high when the predicted value and the actual value of Korean pigs measured by AutoFom III were compared.

In Korea, pig carcass grade is measured according to 21 criteria such as sex, appearance, meat quality, and defects based on carcass weight and backfat thickness [16] (Table 1). And Fig. 1 shows the pig carcass characteristics by grade according to sex through a box plot.

According to KAPE [13], the price per kg of pork was 4,222 won for grade 1+, 4,134 won for grade 1, and 3,960 won for grade 2. Therefore, pig carcass grade is an important factor that shapes the final market price of finishing pigs.

Big data analysis technology is an essential element when analyzing large-capacity data, both structured and unstructured, to extract available information and to actively respond to or predict changes in the pig industry based on analyzed data [17]. It has been predicted that the number of

Table 1. Korean pig carcass grading system

Primary carcass grade	Carcass weight (kg)	Backfat thickness (mm)
1^+	83–92	17–24
1	80–82	15–27
	83–92	15–16
	83–92	25–27
	93–97	15–27
2	Neither 1^+ nor 1	

Adapted from MAFRA with CC-BY [38].

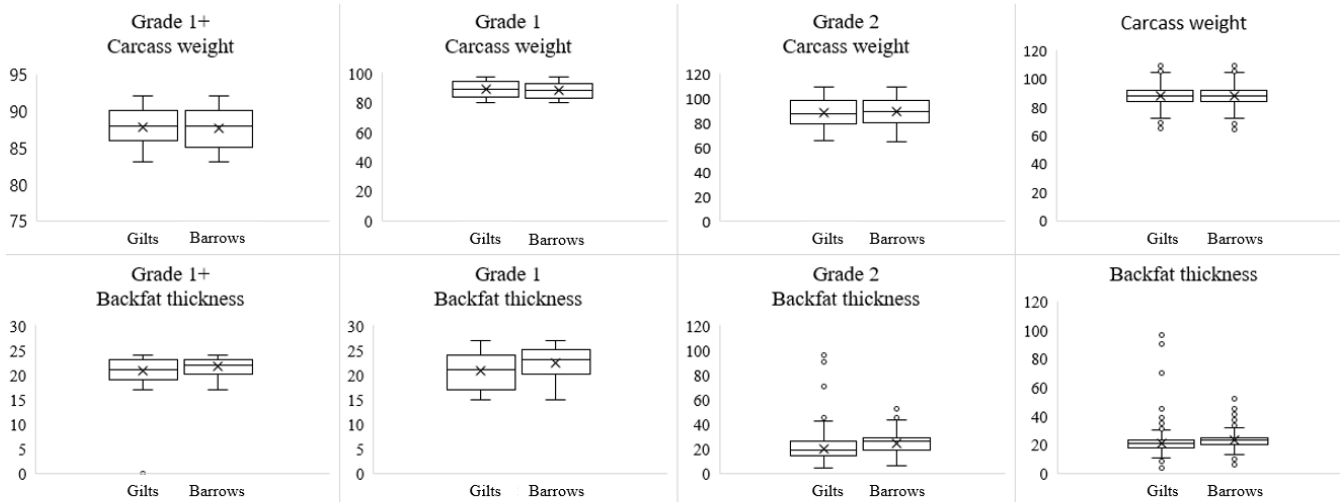

Fig. 1. **Box plot of characteristics of carcass weight and backfat thickness of gilts and barrows.**

clivestock slaughtered will increase in the future. Thus, accumulated data will increase accordingly. Most papers that have compared gilts and barrows so far have compared carcass weight and backfat thickness as well as meat quality. However, very few studies have compared seven primal cuts. In addition, the number of samples investigated was small. One study has reported few data comparing carcass yields from gilts and barrows [18]. Therefore, the purpose of this study was to compare characteristics of pork belly of gilts and barrows, weights of seven primal cuts, and differences in carcass characteristics according to the Korean pig carcass grading system based on data measured with an AutoFom III.

MATERIALS AND METHODS

Animals

A total of 350,719 LYD crossbred pigs were used as experimental materials, including 176,461 gilts and 173,718 barrows. All pigs were bred and slaughtered under the same environment from January 2019 to December 2019. And the feed was provided by the Dodram pig farmers' association in accordance with specific standards of Dodram union. All pigs were transferred to Dodram LPC in Anseong, Gyeonggi Province, Korea and slaughtered in accordance with the Livestock Sanitation Management Act.

Measurement of pig carcass weight and backfat thickness

Pig carcass weight was measured with an electronic scale and expressed in unit of kg. Backfat thicknesses between the last thoracic vertebra and the first lumbar vertebrae and between the 11th and 12th lumbar vertebrae of the left half carcass were measured with a ruler and expressed in unit of mm. The average of two backfat thickness values was calculated.

Measurement of primal cut weight and content of pork belly using AutoFom III

AutoFom III was used after the head was removed and before evisceration of the carcass. AutoFom III is an equipment that performs measurement using ultrasound. It is largely divided into four parts: an ultra-sound transducer array, an acquisition module, a data processing workstation, and a personal computer. It also has 16 ultrasound transducers that are excited in turn with a repeated

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frequency of about 5 kHz. As the carcass is scanned, an ultrasound image is generated, and 48 image parameters are generated that provide information on lean meat and fat yield [15]. Further methods of using AutoFom III have been described in our previous study [18]. Carcass weight, backfat thickness, pork belly characteristics, and weights of seven primal cuts (belly, Boston butt, ribs, tenderloin, loin, picnic shoulder, ham) were measured with the AutoFom III equipment based on the data classified by sex of the pig.

Statistical analysis

A *t*-test was used to test the significance of each investigation. Skewness and Kurtosis were measured to know the disperse of each investigated graph. The regression equation was calculated using weights of seven parts by dividing the carcass by sex and placing the carcass weight as the dependent variable (y_i). Afterwards, coefficient of determination and correlation were calculated. Data of sex and grade were investigated using the following multiple linear regression model.

$$yi = \mu + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7$$

where μ was the intercept and β was the slope of the independent variable x_1, which was the weight of 7 cut meats measured by AutoFom III. x_1 was pork belly, x_2 was pork loin, x_3 was rib, x_4 was sirloin, x_5 was tenderloin, x_6 was forelimb, and x_7 was hind leg. All statistical analyses were performed using SPSS software version 25.0 (SPSS, Chicago, IL, USA).

RESULTS AND DISCUSSION

In Table 2, skewness and kurtosis of carcass weight and backfat thickness were measured to investigate characteristics and distribution according to sex and grade. Fig. 2 shows the distribution of carcass weight and backfat thickness through a box plot. A normal distribution is a case where the mean, median, and mode all agree with skewness and kurtosis of 0. However, in this study, skewness showed negative values for carcass weight and backfat thickness of all sexes with grade 1+,

Table 2. Disperse characteristics of carcass weight and backfat thickness of gilts and barrows[1)]

Items	Weight		Thickness	
	Skewness[2)]	Kurtosis[3)]	Skewness	Kurtosis
1+ grade carcass				
Gilts	−0.117	−1.014	−0.184	−0.978
Barrow	−0.017	−1.053	−0.624	−0.511
1 grade carcass				
Gilts	−0.054	−1.414	−0.006	−1.374
Barrows	0.110	−1.352	−0.585	−0.899
2 grade carcass				
Gilts	0.206	−1.173	0.382	−0.489
Barrows	0.051	−1.042	−0.440	−0.804
All of grades carcass				
Gilts	0.222	0.357	0.164	1.170
Barrows	0.285	0.350	0.108	0.409

[1)]Population number for gilts and barrows were 176,461 and 173,718, respectively.

[2)]Skewness means that the degree to which the distribution is skewed out of symmetry.

[3)]Kurtosis means that the sharpness of the frequency distribution.

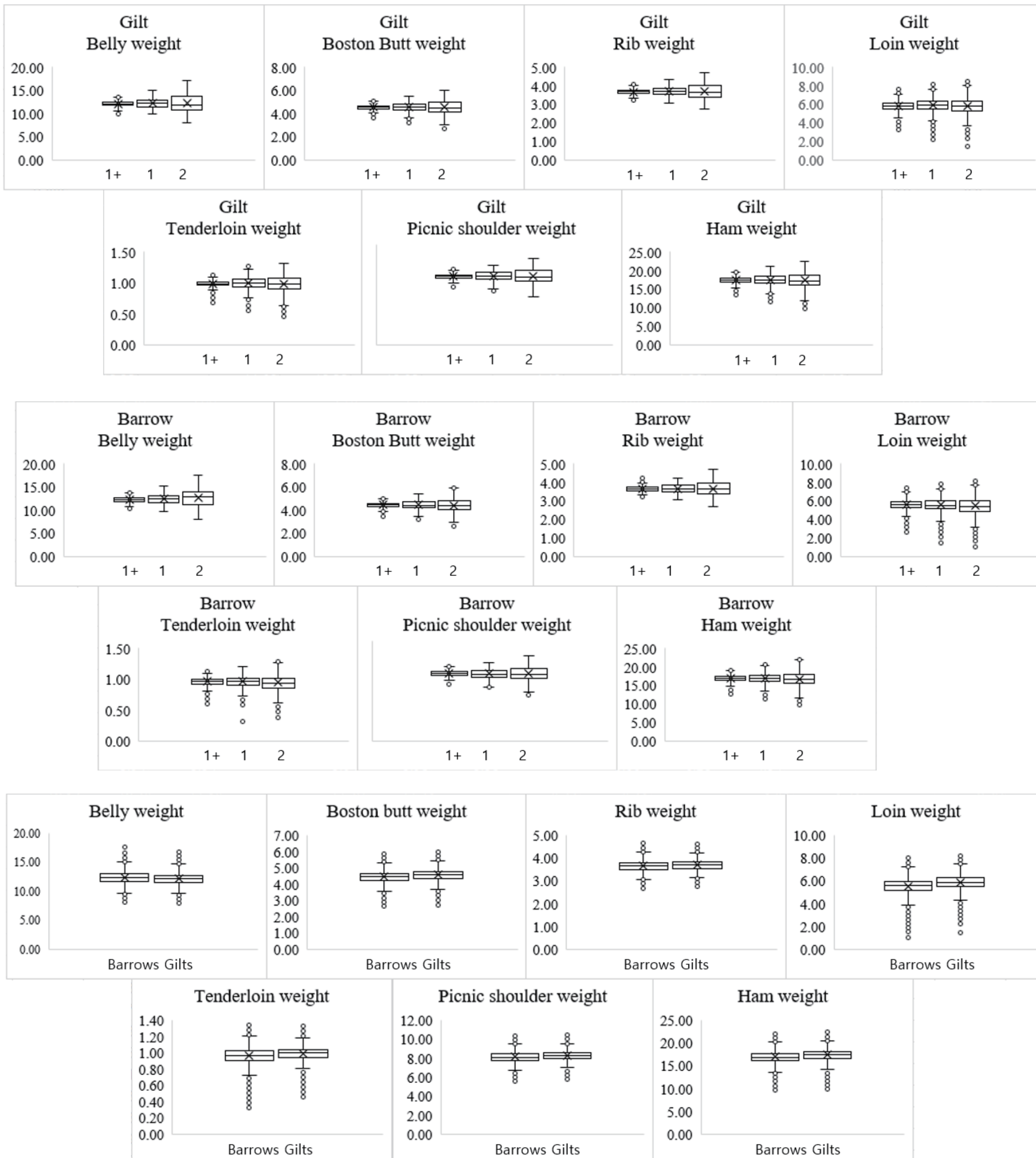

Fig. 2. **Box plot of lean amount by part of gilts and barrows measured by AutoFom III.**

carcass weights of gilts with grade 1, backfat thickness of all sexes, and barrows with grade 2 (Table 2). Except for this, skewness and kurtosis of carcass weight and backfat thickness showed positive values (k > 0, Table 2). If the skewness has a negative value, it is interpreted that the distribution is skewed to the left. If it has a positive value, it is interpreted to be skewed to the right. However,

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according to Kline [19], if the absolute value of skewness is less than 3 and the absolute value of Kurtosis is less than 7, then normal distribution is suitable. Results showed that the absolute value of skewness was less than 3 and the absolute value of kurtosis was less than 7, conforming to normality (Table 2).

There was no significant difference in carcass weight or backfat thickness for grade 1+ between gilts and barrows (both $p > 0.05$). On the other hand, for grade 1, the carcass weight of gilts showed a significantly higher value than that of barrows. For grade 2, the carcass weight of gilts showed a significantly lower value than that of barrows. Except for grade 1+, backfat thickness of barrow was significantly thicker than that of gilts. Overall, gilts showed a tendency to be heavier than that of barrows in the case of carcass weight, whereas barrows tended to have thicker backfat thickness than gilts ($p < 0.05$, Table 3). These results were contrary to results of Larzul et al. [20] and Kim and In [21]. They showed that barrows had higher carcass weight and thicker backfat. Kim and In [21] have found that barrows have heavier carcass weight than gilts without showing significant difference ($p > 0.05$), although barrows have thicker backfat than gilts ($p < 0.05$). The present study showed different results of carcasses of gilts and barrows compared to results of Kim and In [21]. This might be due to differences in breeding area, feed, and age at marketing. According to the study of Larzul et al. [20], gilts grew later than barrows. Thus, their carcass weights were less. However, backfat thickness in the study of Larzul et al. [20] was similar to that of the present study. The reason why carcass weight values of gilts and barrows were opposite from those in the study of Larzul et al. [20] might be due to differences in breed, breeding area, and feed.

Gilts and barrows were classified according to the Korean pig carcass grading system. Results are presented in Table 4. According to the Korean pig carcass grading system, in the case of gilts (n = 176,461), grade 1+showed the largest proportion at 39.13% (n = 69,049), followed by grade 1 at 37.32% (n = 65,850) and grade 2 at 23.55% (n = 41,562). On the other hand, in the case of barrows

Table 3. Pig carcass weight and backfat thickness[1)]

Items	Gilt[2)]	Barrow
Carcass weight		
1+ grade	87.57 ± 2.65	87.83 ± 2.62
1 grade	88.65 ± 5.41[a]	88.01 ± 5.32[b]
2 grade	88.16 ± 9.63[b]	88.54 ± 9.19[a]
All of grades	88.21 ± 5.97[a]	88.10 ± 6.13[b]
Backfat thickness		
1+ grade	20.87 ± 2.04	21.68 ± 1.91
1 grade	20.69 ± 3.92[b]	22.43 ± 3.64[a]
2 grade	20.07 ± 6.91[b]	24.51 ± 6.70[a]
All of grades	20.61 ± 4.33[b]	22.78 ± 4.47[a]

[1)] Each value is presented as mean ± SD.

[2)] Population numbers for Gilts and Barrows were 176,461 and 173,718, respectively.

[a,b] Means within the same row with different superscripts are significantly different ($p < 0.05$).

Table 4. Grade percentage of sex according to the Korean pig meat grading system

Items[1)]	1+[2)]	1	2
Gilt	39.13%	37.32%	23.55%
Barrow	33.88%	37.97%	28.13%

[1)] Population numbers for gilts and barrows were 176,461 and 173,718, respectively.

[2)] Population numbers for grades 1+, 1, and 2 were 127,911, 131,839, and 90,429, respectively.

(n = 173,718), grade 1 showed the highest proportion at 37.97% (n = 65,989), followed by grade 1+ at 33.88% (n = 58,862) and grade 2 at 28.13% (n = 48,867). Results shown in Table 4 were consistent with results of Kim [17]. Both showed that gilts had the highest proportion of grade 1+ and barrows had the highest proportion of grade 1. A similar trend was found for the percentage of pigs slaughtered in 2019 based on the data released by the Livestock Products Quality Assessment Service in 2019 [12]. These results were also similar to results of Kress et al. [22], where S, the highest grade of gilts, showed a higher ratio than that of barrows. Although pig carcass grade used in Europe differs from that in Korea in terms of meat production, the high proportion of the highest grade in gilts cannot be ignored.

In Table 5, skewness and kurtosis were measured to investigate the disperse of seven primal cuts according to sex and grade. Measurements of weights for the seven primal cuts shown in Table 5 were estimated with AutoFom III. In the above result, in the case of comparison between gilts and barrows by grade, as grade decreased, the value of skewness increased, showing a tendency to approach 0. Also, most values of kurtosis were negative, showing a less sharping shape. In the case of overall comparison between gilts and barrows, the value of skewness was negative for loin and ham of gilts and barrows and for tenderloin of gilts. Seven primal cuts showing negative values can be interpreted as skewing the distribution to the left. On the other hand, in the case of kurtosis, all areas of gilts and barrows showed positive values ($k > 0$, Table 5). Skewness and kurtosis did not indicate 0 because the mean, median, and mode did not match. However, the normality was verified according to Kline [19].

As a result of measuring weights of seven primal cuts with AutoFom III, for all grades of pork belly, the most popular cut in Korea, barrows showed significantly higher values than gilts ($p < 0.05$). Except for pork belly, amounts of the remaining six primal cuts showed higher values in gilts than in barrows. In the study of Kress et al. [22], gilts showed significantly higher values of areas such as ham and shoulder than barrows. In addition, similar results were found for pork belly, which showed a higher value in barrows than in gilts. In Table 6 carcass weights of gilts showed significantly higher values than those of barrows, which might be the reason why all parts except pork belly showed high values in gilts than in barrows ($p < 0.05$). The reason why gilts showed higher values of carcass weight and lean meat content than barrows was similar to that in one study [23] that found that estrogen of gilt hormone could improve protein deposition, similar to research results of Tanghe et al. [24] and other dissection experiments [25]. Also, compared to gilts and slow-growing pigs, barrows and fast-growing pigs might have higher amounts of pork belly. The fact that loin, picnic shoulder, and Boston butt were produced more in gilts than in barrows was consistent with a previous study [26], suggesting that there were also differences according to growth rate. In the case of the picnic shoulder, it was mentioned that it increased with the slaughter weight. It can also be explained by growth difference between pork belly and other six parts cut of meat due to allometric growth [27].

As a result of measuring characteristics of pork belly, the most popular cut in Korea, with AutoFom III, gilts showed significantly higher values of lean meat weight than barrows. However, barrows showed significantly higher values of subcutaneous fat and intermuscular fat than gilts ($p < 0.05$, Table 7). According to sex and growth rate, the amount of pork belly and fat content of pork belly could be different. Fast-growing pigs have higher amounts of pork belly and fat contents in pork belly than slow-growing pigs [28]. In addition, a higher fat accumulation has been observed in barrows than in gilts in a previous study [29].

This can be explained by the deposition of more protein by estrogen of gilt hormone. According to Christoffersen et al. [30], castration almost eliminates testosterone. However, testosterone deficiency can increase food intake and body fat, resulting in a large amount of fat deposition.

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Table 5. Disperse of lean amount by part of barrows and gilts measured by AutoFom III

Items	Gilt[1]		Barrow	
	Skewness[2]	Kurtosis[3]	Skewness	Kurtosis
Belly				
1+	0.093	−0.21	0.061	−0.26
1	0.009	−0.99	0.061	−0.93
2	0.204	−1.13	−0.086	−0.97
All grades	0.227	0.339	0.176	0.325
Boston butt				
1+	−0.18	−0.14	−0.13	−0.16
1	−0.10	−0.79	0.10	−0.72
2	0.21	−0.79	0.30	−0.63
All grades	0.014	0.408	0.048	0.369
Rib				
1+	−0.10	−0.57	−0.02	−0.59
1	−0.05	−1.17	0.16	−1.08
2	0.23	−0.99	0.26	−0.85
All grades	0.226	0.329	0.294	0.328
Loin				
1+	−0.25	0.28	−0.19	0.18
1	−0.24	0.04	−0.11	−0.02
2	−0.07	−0.01	0.05	−0.02
All grades	−0.131	0.484	−0.106	0.425
Tenderloin				
1+	−0.23	0.201	−0.18	0.13
1	−0.18	−0.28	−0.01	−0.24
2	0.11	−0.45	0.23	−0.33
All grades	−0.025	0.449	0.008	0.411
Picnic shoulder				
1+	−0.13	−0.37	−0.19	0.18
1	−0.08	−0.98	−0.11	−0.02
2	0.23	−0.90	0.30	−0.75
All grades	0.059	0.372	0.092	0.325
Ham				
1+	−0.23	0.05	−0.17	−0.02
1	−0.14	−0.56	0.05	−0.52
2	0.18	−0.65	0.28	−0.51
All grades	−0.119	0.509	−0.076	0.289

[1]Population numbers for gilts and barrows were 176,461 and 173,718, respectively.

[2]Skewness means that the degree to which the distribution is skewed out of symmetry.

[3]Kurtosis means that the sharpness of the frequency distribution.

Combining this with the study of Escobar-Morreale et al. [31] showing that low testosterone levels in men could cause abdominal obesity, it can be seen that amounts of pork belly and fat contents in barrows are higher than those in gilts. Newcom et al. [32] have shown a trend consistent with the finding of higher production of pork belly from barrows than from gilts. However, in the study of Kress et al. [22], gilts showed no significant difference value compared to barrows ($p < 0.0001$).

Table 6. Lean meat weights of seven primal cuts as measured by AutoFom III[1)]

Items	Gilt[2)]	Barrow
Belly		
1+ Grade	12.12 ± 0.52[b]	12.29 ± 0.54[a]
1 Grade	12.24 ± 0.90[b]	12.40 ± 0.90[a]
2 Grade	12.19 ± 1.57[b]	12.64 ± 1.54[a]
All Grades	9.94 ± 0.70[b]	10.10 ± 0.68[a]
Boston Butt		
1+ Grade	4.55 ± 0.20[a]	4.46 ± 0.20[b]
1 Grade	4.59 ± 0.32[a]	4.45 ± 0.32[b]
2 Grade	4.56 ± 0.49[a]	4.43 ± 0.48[b]
All Grades	3.89 ± 0.32[a]	3.76 ± 0.33[b]
Rib		
1+ Grade	3.67 ± 0.11[a]	3.65 ± 0.12[b]
1 Grade	3.70 ± 0.21[a]	3.65 ± 0.21[b]
2 Grade	3.68 ± 0.35[a]	3.65 ± 0.34[b]
All Grades	3.67 ± 0.23[a]	3.62 ± 0.23[b]
Tenderloin		
1+ Grade	0.99 ± 0.05[a]	0.96 ± 0.06[b]
1 Grade	1.00 ± 0.08[a]	0.96 ± 0.08[b]
2 Grade	0.99 ± 0.11[a]	0.95 ± 0.11[b]
All Grades	0.99 ± 0.08[a]	0.96 ± 0.08[b]
Loin		
1+ Grade	5.83 ± 0.48[a]	5.60 ± 0.49[b]
1 Grade	5.89 ± 0.61[a]	5.55 ± 0.62[b]
2 Grade	5.84 ± 0.78[a]	5.45 ± 0.82[b]
All Grades	6.43 ± 0.64[a]	6.11 ± 0.68[b]
Picnic shoulder		
1+ Grade	8.22 ± 0.28[a]	5.60 ± 0.49[b]
1 Grade	8.29 ± 0.48[a]	5.55 ± 0.62[b]
2 Grade	8.27 ± 0.78[a]	8.09 ± 0.75[b]
All Grades	7.98 ± 0.54[a]	7.75 ± 0.57[b]
Ham		
1+ Grade	17.31 ± 0.77[a]	16.95 ± 0.79[b]
1 Grade	17.45 ± 1.17[a]	16.90 ± 1.18[b]
2 Grade	17.33 ± 1.74[a]	16.75 ± 1.74[b]
All Grades	16.29 ± 1.19[a]	15.69 ± 1.27[b]

[1)]Each value is presented as mean ± SD.

[2)]Population numbers for gilts and barrows were 176,461 and 173,718, respectively.

[a,b]Means within the same row with different superscripts are significantly different ($p < 0.05$).

Such differences in results between the study of Kress et al. [22] and the present study might be due to different breed of pigs used in the experiment. From results shown in Table 7, proportions of pork belly from gilts and barrows were consistent results of a previous study [10,33] showing that pork belly accounted for 13%–18% of carcass weight. Lean meat percentage of pork belly was 22%–55% and Fat percentage was 20%–60%, consistent with above results. In addition, the ratio of subcutaneous fat in pork belly fat was double that of intermuscular fat. According to Hoa et al. [10], Pork belly with a high fat ratio (fat > 31%) was found to have higher meat quality, fatty acid

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Table 7. Weights of lean meat, subcutaneous fat, and muscle fat of pork belly according to sex measured by AutoFom III[1)]

Items	Gilt[2)]	Barrow
Lean meat(kg)		
1+ grade	10.05±0.39[a]	9.45±0.39
1 grade	10.14±0.65[a]	9.95±0.65
2 grade	10.10±1.02[a]	9.92±1.00
All grades	10.10±0.68[a]	9.94±0.70[b]
Lean meat percentage		
1+ grade	55.57±2.17[a]	54.53±2.28
1 grade	55.58±2.74[a]	54.04±2.85
2 grade	55.56±3.82[a]	52.80±3.99
All grades	55.57±2.84[a]	53.86±3.13[b]
Subcutaneous fat weight		
1+ grade	4.89±0.38	5.03±0.39[a]
1 grade	4.94±0.57	5.13±0.57
2 grade	4.92±0.96	5.37±0.95[a]
All grades	4.92±0.63[b]	5.16±0.67[a]
Subcutaneous fat percentage		
1+ grade	26.51±1.33	26.98±1.40[a]
1 grade	26.49±1.65	27.26±1.70[a]
2 grade	26.46±2.26	27.94±2.32[a]
All grades	26.49±1.71[b]	27.36±1.85[a]
Intermuscular fat weight		
1+ grade	2.29±0.28	2.41±0.29[a]
1 grade	2.32±0.40	2.49±0.42[a]
2 grade	2.31±0.66	2.68±0.67[a]
All grades	2.30±0.44[b]	2.52±0.48[a]
Intermuscular fat percentage		
1+ grade	12.41±1.28	13.06±1.36[a]
1 grade	12.41±1.62	13.36±1.70[a]
2 grade	12.45±2.29	14.13±2.40[a]
All grades	12.42±1.69[b]	13.47±1.88[a]
Belly fat percentage		
1+ grade	38.89±2.45	40.06±2.58[a]
1 grade	38.88±3.10	40.62±3.23[a]
2 grade	38.91±4.34	42.06±4.55[a]
All grades	38.89±3.22[b]	40.83±3.56[a]
Ratio belly weight to carcass weight		
1+ grade	13.77	13.97
1 grade	13.75	14.09
2 grade	13.85	14.20
All grades	13.81	14.11

[1)]Each value is presented as mean ± SD.

[2)]Population numbers for gilts and barrows were 176,461 and 173,718, respectively.

[a,b]Means within a same row with different superscripts are significantly different ($p < 0.05$).

content, and flavor compound, which were important for eating quality. Therefore, both gilts and barrows showed a high-fat content (over 31%) of pork belly. Thus, it could be considered that the taste of pork belly from both sexes is good. According to Kim [26], when sensory of pork belly with less than 40% fat was compared to that of pork belly with 40% to 45% fat, pork belly with more than 40% fat showed higher juiciness, tenderness, flavor, fattiness, and overall Palatability. However, there was no significant difference value. However, based on the data that the preference for pork belly with intermuscular fat content of 13% to 15% is the highest [34] and that the highest successful bid price is formed [35], It is thought that the pork belly of barrows is more preferred. It was found that the amount of intermuscular fat had a significant correlation with both taste and flavor of meat [36].

Correlation analysis was conducted to investigate the relationship between carcass weight and weights of seven primal cuts according to grade and between backfat thickness and weights of seven primal cuts (Tables 8 and 9). In both gilts and barrows, correlations between carcass weight and seven primal cuts showed generally high values. However, correlations between backfat thickness and seven primal cuts showed low values. In the case of gilts, the correlation between the amount of pork belly and carcass weight was 0.725 for grade 1+, 0.901 for grade 1, and 0.960 for grade 2, indicating a high correlation coefficient (p < 0.01). In the case of barrows, the correlation between the amount of pork belly and carcass weight was 0.714 for grade 1+, 0.888 for grade 1, and 0.9492 for grade 2, showing a high correlation coefficient (p < 0.01). Correlations between carcass weight and weights of seven primal cuts showed generally high correlation coefficients (p < 0.01, Table 8), whereas correlations between backfat thickness and weights of seven primal cuts showed low values,

Table 8. Correlation coefficients between characteristics of carcass and weights of seven primal cuts of gilts

Items	Belly	Boston Butt	Ribs	Tenderloin	Loin	Picnic Shoulder	Ham
Carcass weight							
1+	0.725**	0.718**	0.880**	0.553**	0.401**	0.803**	0.635**
1	0.901**	0.856**	0.948**	0.733**	0.579**	0.903**	0.799**
2	0.960**	0.906**	0.968**	0.811**	0.670**	0.938**	0.864**
Backfat thickness							
1+	0.239**	−0.137**	−0.066**	−0.169**	−0.168**	−0.124**	−0.155**
1	0.469**	0.032**	0.149**	−0.058**	−0.127**	0.068**	−0.015**
2	0.648**	0.244**	0.372**	0.124**	−0.002**	0.290**	0.184**

**p < 0.01.

Table 9. Correlation coefficients between characteristics of carcass and weights of seven primal cuts of barrows

Items	Belly	Boston Butt	Ribs	Tenderloin	Loin	Picnic Shoulder	Ham
Carcass weight							
1+	0.714**	0.702**	0.874**	0.534**	0.389**	0.389**	0.618**
1	0.888**	0.841**	0.941**	0.714**	0.562**	0.562**	0.780**
2	0.949**	0.885**	0.961**	0.778**	0.635**	0.924**	0.836**
Backfat thickness							
1+	0.248**	−0.100**	−0.043**	−0.129**	−0.128**	−0.128**	−0.117**
1	0.443**	−0.001**	0.106**	−0.080**	−0.136**	−0.136**	−0.045**
2	0.616**	0.169**	0.300**	0.056**	−0.052**	0.219**	0.110**

**p < 0.01.

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including negative values ($p > 0.01$, Table 8). Overall, correlation coefficients between carcass weight and seven primal cuts showed higher values as the grade decreased. On the other hand, correlation coefficients between backfat thickness and the seven primal cuts showed a tendency to increase with negative values as the grade decreased.

A regression analysis was performed to investigate relationships between carcass weight and seven primal cuts. Multiple regression analysis was performed with carcass weight as the dependent variable and the weight of each of the seven primal cuts as the independent variable. The linear regression equation between carcass weight and seven primal cuts by grade according to sex is shown as follows:

Gilts:

Grade 1+:

$$y = 6.723 - 1.578x_1 - 0.892x_2 + 52.001x_3 + 5.507x_4 + 14.578x_5 - 14.123x_6 - 1.660x_7;$$

Grade 1:

$$y = 2.164 - 1.202x_1 - 20797x_2 + 54.464x_3 + 5.766x_4 + 19.602x_5 - 14.98x_6 - 1.7x_7;$$

Grade 2:

$$y = -2.23518 + 1.016x_1 - 9.906x_2 + 49.406x_3 + 4.869x_4 + 31.954x_5 - 13.012x_6 - 1.33x_7$$

Barrows:

Grade 1+:

$$y = 5.195 - 1.131x_1 - 2.053x_2 + 50.754x_3 + 4.964x_4 + 17.16x_5 - 13.867x_6 - 1.36x_7;$$

Grade 1:

$$y = 0.37 - 0.276x_1 - 5.46x_2 + 51.419x_3 + 4.943x_4 + 24.984x_5 - 13.958x_6 - 1.351x_7;$$

Grade 2:

$$y = -3.841 + 1.888x_1 - 12.546x_2 + 46.687x_3 + 4.215x_4 + 37.071x_5 - 12.013x_6 - 1.074x_7$$

The coefficient of determination is divided into grades according to sex. For gilts, it was 0.943 for grade 1+, 0.984 for grade 1, 0.993 for grade 2. For barrows, it was 0.943 for grade 1+, 0.982 for grade 1, and 0.993 for grade 2, showing high values. These showed a similar trend to a previous study [15]. Park et al. [11] have made a regression equation without sex distinction, whereas this study created a regression equation between grades of carcass weight and 7 primal cuts weights by classifying sex. Considering that a fairly high coefficient of determination was obtained through the regression equation, it was thought that weights of the seven primal cuts divided by sex in the Korean pig industry could be easily predicted.

This study analyzed and compared to carcass characteristics of gilts and barrows, the weight of primal cut, and the characteristics of pork belly measured by AutoFom III. AutoFom III data were estimated with a mathematical formula developed based on anatomical experiments [37]. The reliability of the estimate has been proven in a previous study by Choi et al. [15]. Carcass weights of gilts were significantly higher than those of barrows ($p < 0.05$). For all cuts except for the pork belly, gilts showed higher values ($p < 0.05$) than barrows. Also, the increase in the amount of pork belly and the increase in body fat due to the lack of testosterone in barrows resulted in higher amounts of pork belly of barrows and higher muscle fat content than gilts. In other words, it is considered that the pork belly, which consumers prefer, appears more in barrows than in gilts. The proportion of intermuscular fat was also higher in the pork belly of barrows. Thus, it is thought that the pork belly of barrows is better than that of gilts.

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