Food Science of Animal Resources

Food Sci. Anim. Resour. 2024 November 44(6):1462~1469
DOI https://doi.org/10.5851/kosfa.2024.e76

pISSN : 2636-0772 eISSN : 2636-0780
http://www.kosfaj.org

SHORT COMMUNICATION

Relationship of Hot Carcass Weight and Back Fat Thickness with the Fatness of Whole Pork Belly and Belly Slices

Kyung Jo[1], Seonmin Lee[1], Seul-Ki-Chan Jeong[1], Hyeun Bum Kim[2], Pil Nam Seong[3], Dae-Hyun Lee[4], and Samooel Jung[1,*]

[1]Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 34134, Korea
[2]Department of Animal Resources Science, Dankook University, Cheonan 16890, Korea
[3]National Institute of Animal Science, Rural Development Administration, Wanju 55365, Korea
[4]Department of Biosystems Machinery Engineering, Chungnam National University, Daejeon 34134, Korea

OPEN ACCESS

Received July 23, 2024
Revised August 3, 2024
Accepted August 8, 2024

***Corresponding author** : Samooel Jung
Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 34134, Korea
Tel: +82-42-821-5774
Fax: +82-42-825-9754
E-mail: samooel@cnu.ac.kr

***ORCID**
Kyung Jo
https://orcid.org/0000-0002-3006-5396
Seonmin Lee
https://orcid.org/0000-0002-5713-1795
Seul-Ki-Chan Jeong
https://orcid.org/0000-0002-2163-8340
Hyeun Bum Kim
https://orcid.org/0000-0003-1366-6090
Pil Nam Seong
https://orcid.org/0000-0003-2915-1059
Dae-Hyun Lee
https://orcid.org/0000-0001-9544-5974
Samooel Jung
https://orcid.org/0000-0002-8116-188X

Abstract This study evaluated the correlation between hot carcass weight (HCW), back fat thickness (BFT), and fatness of whole pork belly and belly slices. Pork bellies were obtained from 50 barrows and 50 gilts. The fat content (v/v) of the whole pork belly and belly slices was measured using computer tomography and hyperspectral image analysis, respectively. Barrows and gilts showed significant differences only for HCW ($p<0.05$). The fat content of pork belly slices varied with location and was the highest at the 10th thoracic vertebra (TV). Although no significant difference was observed in the fat content between the belly slices of the 6th TV and the 12th–14th TVs ($p>0.05$), a difference in the fat distribution was observed. HCW and BFT were significantly correlated with the fat content of whole pork belly, but not with the fat content of pork belly slices. Therefore, HCW and BFT are not suitable for monitoring the fatness of pork belly slices, and further research on the factors that can be used for monitoring the fatness of pork belly is necessary.

Keywords pork belly, fatness, carcass weight, back fat thickness, meat quality

Introduction

Pork belly has the highest fat content among various pork cuts and is highly preferred by consumers in some countries (Albano-Gaglio et al., 2024; Jo et al., 2023; Munezero and Kim, 2023). Pork belly consists of various muscle and intermuscular fat layers (Jeong et al., 2024; Jo et al., 2022) and has different characteristics depending on its location (cranial, caudal, dorsal, and ventral sides) in the muscle and fat layers (Albano-

Gaglio et al., 2024; Lee et al., 2018).

Fat in pork belly is important for sensory qualities such as flavor, texture, and juiciness, and for processing properties such as firmness (Ahammad and Kim, 2024; Jo et al., 2024; Kim et al., 2023). Therefore, pork belly with low fat content may have poor quality. However, the high fat content of pork belly is also a concern for consumers because of its high calory and saturated fatty acid content (Gaffield et al., 2022; Lee et al., 2023; Seo et al., 2023). In addition, the high fatness in pork belly reduces the processing yield because thick fat layers are generally discarded during processing. Therefore, information on the fatness of pork bellies can be helpful for the evaluators of carcass grades, producers, and consumers. In particular, information about the fatness of pork belly located in the region from the 10^{th} to 14^{th} thoracic vertebrae (TV) may be more important because of the high fat content in these pork belly slices (Lee et al., 2018; Trusell et al., 2011).

Various factors such as genotype (commercial pigs with crossbreeds, pure breed pigs), sex (male, female, physical, or immune castration), and diet (high energy intake, fat sources) have been reported to influence the fatness of carcasses, and consequently the fatness of pork cuts (Albano-Gaglio et al., 2024; Duziński et al., 2015; Font-i-Furnols et al., 2023; Gaffield et al., 2022; Harsh et al., 2017; Overholt et al., 2016). The results of previous studies may imply that owing to the effects of the various factors described above, changes in the fatness of pork carcasses are accompanied by the changes in the fatness of pork cuts. Hot carcass weight (HCW) and back fat thickness (BFT) of pork carcasses are generally used to predict carcass fatness (Duziński et al., 2015; Harsh et al., 2017; Ko et al., 2023). Previous studies have reported that the pork belly firmness is positively correlated with the HCW of pork carcasses, which is positively correlated with the pork belly fatness (Albano-Gaglio et al., 2024; Harsh et al., 2017). In addition, Uttaro and Zawadski (2010) reported a high correlation (r=0.86) between BFT and the pork belly fat content. However, the relationship between HCW, BFT, and pork belly fatness, particularly the fatness of belly slices from different locations, has not been sufficiently reported.

Therefore, in this study, we measured the fatness (v/v) of whole pork belly and belly slices from different locations. Additionally, we investigated the effects of HCW and BFT on the fatness of pork belly. Furthermore, the differences in the fatness of belly slices between barrows and gilts were investigated.

Materials and Methods

Pork belly preparation

The pork belly was obtained from pigs (Landrace×Yorkshire×Duroc) raised and slaughtered in commercial systems. Therefore, the rearing environment, diet, and age were not considered as factors affecting the fatness of pork belly in this study. Pork belly was procured from the left half- carcasses of 50 barrows (surgically castrated) and 50 gilts 24 h postmortem; a total of 100 pork bellies were used for this study. Pork bellies were collected in 10 batches (10 pork bellies per batch). The HCW values were measured automatically during the slaughter process. The BFT was measured manually at two sites, between the 11^{th} and 12^{th} TV and between the last TV and the first lumbar vertebra (LV), and the mean values of the two sites were used. The half-carcass was vertically cut from the dorsal to the abdominal area at the positions of the 5^{th} TV and 6^{th} LV, and divided into the front leg, body, and hind leg 24 h postmortem. Subsequently, the pork belly was separated from the body after deboning. The skin and subcutaneous fat of the pork belly were removed, leaving 3 mm of fat. The pork belly was vacuum-packed and transported to the laboratory under refrigeration at 4°C.

Measurement of pork belly fat content

The fat content of pork belly was first measured on the whole pork belly using computed tomography (CT). Then the pork belly was sliced and fat content was measured on the pork belly slices at selected locations using hyperspectral image analysis. To select the location for measuring the fat content of the pork belly slice, the pork belly was divided into three groups (5^{th}–10^{th} TV, 10^{th}–14^{th} TV, and 1^{st}–6^{th} LV) based on the fat distribution and fac content identified through animal muscle atlas (Korea Institute for Animal Products Quality Evaluation, 2024) and previous studies (Lee et al., 2018; Trusell et al., 2011). In the first and third groups, the 6^{th} TV and 4^{th} LV were selected as representative samples respectively. The 10^{th}–14^{th} TV groups were all selected because they were considered important information to consumers due to their high fat content.

The total fat content (v/v) of whole pork belly was measured using CT. The pork belly was positioned with the muscle part downward and scanned from the cranial to the caudal side using a 32-detector-row CT scanner (AlexionTM, Toshiba Medical Systems, Tochigi, Japan). The scan parameters were 120 kVp, 150 mA, slice thickness of 1 mm, rotation time of 0.75 s, and collimation beam pitch of 0.938. The acquired CT images displayed a soft tissue window (window level=40 Hounsfield units, window width=400 Hounsfield units) and were extracted using commercially available software (Xelis, INFINITT Healthcare, Seoul, Korea). The CT images were checked using a picture archiving and communication system. The volume of the muscle and fat in the pork belly in the cross-sectional CT images was estimated using the Vitrea workstation version 7 (Vital Images, Minnetonka, MN, USA).

After a CT scan of the pork belly, the pork belly was vertically sliced from the dorsal side to the ventral side at the positions of the 6^{th}, 10^{th}, 11^{th}, 12^{th}, 13^{th}, and 14^{th} TV and 4^{th} LV (Fig. 1). Seven slices were obtained from each pork belly sample. The fat content (v/v) of the belly slices was measured using hyperspectral image analysis. A hyperspectral image of the belly slice was captured using a snapshot-type Cubert Ultris X20 plus camera (Cubert, Ulm, Germany) in the reflectance mode. Halogen lamps were used as the light source, and images were collected using the CUVIS software (Cubert). The perClass Mira software (perClass BV, Delft, The Netherlands) was used to measure the volume of muscle and fat in the belly slices.

Statistical analysis

For all data, statistical analysis was performed using the SAS software (version 9.4, SAS Institute, Cary, NC, USA). The descriptive statistics of the carcass properties (HCW and BFT) and the fat contents of pork belly were presented in Supplementary Table S1. The univariate procedure was used to test the normality of the data, which was determined using the Shapiro-Wilk ($p>0.05$) test. Comparison of pork belly fatness between barrows and gilts was performed using a t-test for normally distributed data and Wilcoxon's rank sum test for non-normally distributed data. The relationship between continuous data was confirmed using Spearman rank correlation analysis because of the non-normal distribution of some data. The significance of the correlation was set at $p<0.05$.

Results and Discussion

Carcass property and pork belly fatness of barrow and gilt

Carcass properties such as HCW and BFT have been used to monitor the fatness of pork carcasses. In this study, the HCW values for barrow and gilt were 87.67 kg and 89.61 kg, respectively, showing that barrows had significantly lower HCW compared to gilts (Table 1, $p<0.05$). By contrast, there were no significant differences between the BFT values for barrow and gilt ($p>0.05$). Previous studies have reported various results for the HCW and BFT differences between barrows and gilts. Overholt et al. (2016) reported that both HCW and BFT were higher in barrows than in gilts. However, Font-i-Furnols et al. (2023) reported no difference in the HCW between barrows and gilts. Moreover, another study found high BFT in

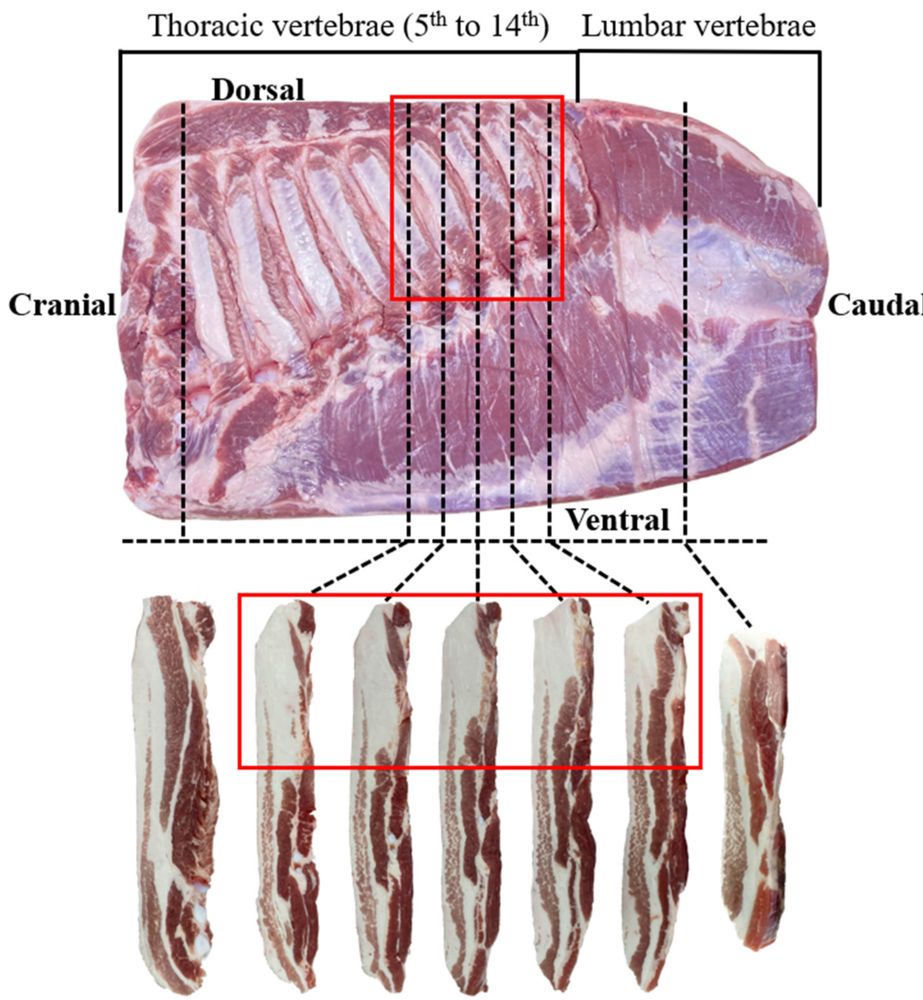

Fig. 1. **Images of whole pork belly and belly slices collected from various location for this study.**

barrows compared to that of gilts, whereas barrows and gilts had similar HCW (Bohrer et al., 2023). The differences between our results and the results obtained in previous studies may be attributed to the differences between the carcasses used in each study. However, previous studies have implied that barrow carcasses are generally fatter than gilt carcasses (Knecht and Duziński, 2016; Overholt et al., 2016). Furthermore, the barrow carcasses and gilt carcasses in this study had similar BFT values, despite the lower HCW for the barrows than for the gilts.

The fat content (v/v) of whole pork belly was 37.65% in barrows and 39.20% in gilts, with no significant difference ($p>0.05$). This result is similar to that of a previous study. Font-i-Furnols et al. (2023) found similar fat contents of minced belly of barrows and gilts with similar HCW. Uttaro and Zawadski (2010) reported that the fat depth measured at the third/fourth last rib in crossbred pork carcasses showed a strong positive correlation ($r=0.86$) with the fat content of the minced belly, whereas no significant correlation was observed between HCW and fat content of the minced belly. In addition, a weak correlation ($r=0.22$) between HCW and fat content of the belly measured by CT has been reported (Albano-Gaglio et al., 2024). In this study, the fat content of whole pork belly was moderately correlated with BFT ($r_s=0.504$) and weakly correlated with HCW ($r_s=0.202$; Table 1). Therefore, the fat content of the whole pork belly in this study may be similar for both sexes because of their similar BFT values. In addition, the fat content of all belly slices did not show differences between barrows and gilts.

Table 1. HCW and BFT of pork carcasses and fat content (v/v) of whole pork belly and belly slices

Variable	Gender		p-value
	Barrow	Gilt	
Carcass properties			
Hot carcass weight (kg)	87.67±3.88	89.61±3.20	0.011
Back fat thickness (mm)	23.27±3.62	22.49±3.90	0.329
Fat content of pork belly			
Belly slice at 6th TV	35.87±6.78^{CD}	35.66±6.24^{CD}	0.944
Belly slice at 10th TV	43.79±6.69^{A}	43.70±7.23^{A}	0.953
Belly slice at 11th TV	40.48±6.86^{AB}	40.90±7.33^{AB}	0.780
Belly slice at 12th TV	38.50±7.56^{BC}	38.56±7.45^{BC}	0.970
Belly slice at 13th TV	36.94±6.70^{BCD}	36.48±7.30^{BCD}	0.759
Belly slice at 14th TV	34.25±6.13^{DE}	34.56±6.35^{D}	0.816
Belly slice at 4th LV	31.65±7.11^{E}	32.02±6.44^{D}	0.429
Whole pork belly	37.65±4.70	39.20±4.98	0.193

Mean±SD.
$^{A–E}$ Different capital letters indicate significant differences in fat content among the belly slices (p<0.05).
HCW, hot carcass weight; BFT, back fat thickness; TV, thoracic vertebrae; LV, lumbar vertebrae.

The fat content of belly slices ranged from 31.65% to 43.77%, and was highest in the belly slice at the 10th TV and lowest in the belly slice at the 4th LV (Supplementary Table S1). This result was similar to that reported by Trusell et al. (2011). They found that the fat content of the pork belly was higher in the middle section than in the other sections when the whole pork belly was divided vertically into five sections between the cranial and caudal. The fat content of the belly slice on the 12th TV was significantly lower than that on the belly slice at 10th TV (p<0.05). The belly slice at the 6th TV showed fat content similar to that of the belly slices at the 12th, 13th, and 14th TV (p>0.05). However, the fat distribution of the belly slices at the 6th TV was different from that of the other TVs (Fig. 1). The fat layer in the belly slice at the 6th TV was evenly distributed from the dorsal to the ventral regions. By contrast, fat accumulated in the dorsal part of the belly slice on the 10th, 11th, 12th, 13th, and 14th TVs (red box in Fig. 1). Trusell et al. (2011) reported that the fat content of the dorsal part of the vertical middle part (similar to the red box in Fig. 1) of the whole pork belly was 75.2%. Therefore, the consumer preference for belly slices at the 10th, 11th, 12th, 13th, and 14th TVs may be low because of the accumulated fat with the small muscle layer. In addition, the removal of the part containing the accumulated fat from the belly slice may damage the producer.

Correlations of hot carcass weight and back fat thickness on the fatness of pork belly

The correlation coefficients (r_s) of HCW and BFT with the fat content of the belly are presented in Table 2. HCW had a correlation coefficient of 0.202 with the fat content of the whole pork belly. Albano-Gaglio et al. (2024) reported a similar correlation coefficient (r=0.22) between HCW and the fat content of whole pork belly. The correlation coefficient between BFT and the fat content of whole pork belly was 0.504, which was higher than the correlation coefficient between HCW and the fat content of whole pork belly. A previous study reported that the correlation coefficient for BFT and fat content of pork belly was 0.86 (Uttaro and Zawadski, 2010). Therefore, BFT was more correlated with the fat content of the whole pork belly than HCW. However, HCW and BFT were not significantly correlated with the fat content of all belly slices. In addition, the

Table 2. Correlation coefficients (r_s) of HCW and BFT for fat contents, and between fat contents of pork belly

Variable	Carcass properties		Fat contents of belly slices						
	HCW	BFT	6th TV	10th TV	11th TV	12th TV	13th TV	14th TV	4th LV
HCW									
BFT	0.237								
Fat contents of belly slices									
6th TV	-[1)]	-							
10th TV	-	-	0.703						
11th TV	-	-	0.721	0.892					
12th TV	-	-	0.679	0.892	0.889				
13th TV	-	-	0.624	0.801	0.813	0.880			
14th TV	-	-	0.745	0.841	0.829	0.832	0.876		
4th LV	-	-	0.664	0.678	0.661	0.671	0.658	0.758	
Fat content of whole belly									
Belly	0.202	0.504	0.209	0.223	0.235	0.325	0.313	0.298	0.245

1) No significant correlation ($p>0.05$).
HCW, hot carcass weight; BFT, back fat thickness; TV, thoracic vertebrae; LV, lumbar vertebrae.

fat content of whole pork belly showed a weak correlation (r_s=0.209–0.325) with the fat content of the belly slices. The fat contents of the belly slices at the 10th, 11th, 12th, 13th, and 14th TVs were strongly correlated (r_s=0.801–0.892). However, the correlation coefficients of the fat content of the belly slice at the 6th TV or 4th LV and the slices at the other TVs were lower than those of the belly slices between the 10th and 14th TVs. These results suggest that the fat content of belly slices varies strongly with location. In addition, neither HCW nor BFT can be used to monitor the fatness of belly slices.

Conclusion

This study aimed to determine whether the HCW and BFT of carcasses are related to the fat content of the whole pork belly and belly slices. There was no significant difference in the fat content of pork belly between the barrow and gilt. Pork belly slices had different fat content and fat distribution depending on the location. HCW and BFT had no significant correlation with the fat content of pork belly. In conclusion, it is difficult to monitor the fatness of belly slices at different locations using HCW and BFT. However, this study is important in that it investigated the correlation by considering the difference in pork belly according to the location. Therefore, further research is needed on factors that can monitor the fatness of pork belly, especially considering differences according to the locations of pork belly.

Supplementary Materials

Supplementary materials are only available online from: https://doi.org/10.5851/kosfa.2024.e76.

Conflicts of Interest

The authors declare no potential conflicts of interest.

Acknowledgements

This study was supported by the Cooperative Research Program for Agriculture, Science, and Technology Development (Project No. PJ01621101) from the Rural Development Administration of the Korea.

Author Contributions

Conceptualization: Jung S. Data curation: Jo K. Formal analysis: Jo K, Lee S, Jeong SKC, Kim HB, Seong PN. Writing - original draft: Jo K. Writing - review & editing: Jo K, Lee S, Jeong SKC, Kim HB, Seong PN, Lee DH, Jung S.

Ethics Approval

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

References

Ahammad GS, Kim IH. 2024. Efficacy of decreasing levels of tryptophan relative to lysine on the performance and meat quality of finishing pigs. Korean J Agric Sci 51:1-8.

Albano-Gaglio M, Zomeño C, Tejeda JF, Brun A, Gispert M, Marcos B, Font-i-Furnols M. 2024. Pork belly quality variation and its association with fatness level. Meat Sci 213:109482.

Bohrer BM, Dorleku JB, Campbell CP, Duarte MS, Mandell IB. 2023. A comparison of carcass characteristics, carcass cutting yields, and meat quality of barrows and gilts. Transl Anim Sci 7:txad079.

Duziński K, Knecht D, Lisiak D, Janiszewski P. 2015. Factors affecting the tissues composition of pork belly. Animal 9:1897-1903.

Font-i-Furnols M, Albano-Gaglio M, Brun A, Tejeda JF, Gispert M, Marcos B, Zomeño C. 2023. The effect of immunocastration of male and female Duroc pigs on the morphological, mechanical and compositional characteristics of pork belly. Meat Sci 204:109263.

Gaffield KN, Boler DD, Dilger RN, Dilger AC, Harsh BN. 2022. Effects of feeding high oleic soybean oil to growing–finishing pigs on loin and belly quality. J Anim Sci 100:skac284.

Harsh BN, Arkfeld EK, Mohrhauser DA, King DA, Wheeler TL, Dilger AC, Shackelford SD, Boler DD. 2017. Effect of hot carcass weight on loin, ham, and belly quality from pigs sourced from a commercial processing facility. J Anim Sci 95:4958-4970.

Jeong SKC, Jo K, Lee S, Jeon H, Kim S, Han S, Woo M, Kim HB, Seong PN, Jung S. 2024. Relationship between the pH of *semispinalis capitis* muscle and the quality properties of pork shoulder butt and belly slices. Food Chem X 23:101704.

Jo K, Lee S, Jeong HG, Lee DH, Kim HB, Seol KH, Kang S, Jung S. 2022. Prediction of cooking loss of pork belly using quality properties of pork loin. Meat Sci 194:108957.

Jo K, Lee S, Jeong HG, Lee DH, Yoon S, Chung Y, Jung S. 2023. Utilization of electrical conductivity to improve prediction accuracy of cooking loss of pork loin. Food Sci Anim Resour 43:113-123.

Jo K, Lee S, Jeong SKC, Lee DH, Jeon H, Jung S. 2024. Hyperspectral imaging–based assessment of fresh meat quality: Progress and applications. Microchem J 197:109785.

Kim S, Choi J, Kim ES, Keum GB, Doo H, Kwak J, Ryu S, Choi Y, Pandey S, Lee NR, Kang J, Lee Y, Kim D, Seol KH, Kang SM, Bae IS, Cho SH, Kwon HJ, Jung S, Lee Y, Kim HB. 2023. Evaluation of the correlation between the muscle fat ratio of pork belly and pork shoulder butt using computed tomography scan. Korean J Agric Sci 50:809-815.

Knecht D, Duziński K. 2016. The effect of sex, carcass mass, back fat thickness and lean meat content on pork ham and loin characteristics. Arch Anim Breed 59:51-57.

Ko E, Park Y, Park K, Woo C, Kim J, Kim K, Choi J. 2023. Comparison of pork belly characteristics and weights of primal cuts between gilt and barrow of Landrace × Yorkshire × Duroc pigs measured by AutoFomIII. J Anim Sci Technol 65:412-426.

Korea Institute for Animal Products Quality Evaluation. 2024. Animal muscle atlas. Available from: https://www.ekapepia.com/contents/cont.do?menuId=menu100255. Accessed at Feb 1, 2024.

Lee EA, Kang JH, Cheong JH, Koh KC, Jeon WM, Choe JH, Hong KC, Kim JM. 2018. Evaluation of whole pork belly qualitative and quantitative properties using selective belly muscle parameters. Meat Sci 137:92-97.

Lee S, Jo K, Jeong SKC, Jeon H, Choi YS, Jung S. 2023. Recent strategies for improving the quality of meat products. J Anim Sci Technol 65:895-911.

Munezero O, Kim IH. 2023. Effects of glycozyme addition on fatty acid and meat quality characteristics of growing pigs. Korean J Agric Sci 50:337-346.

Overholt MF, Arkfeld EK, Mohrhauser DA, King DA, Wheeler TL, Dilger AC, Shackelford SD, Boler DD. 2016. Comparison of variability in pork carcass composition and quality between barrows and gilts. J Anim Sci 94:4415-4426.

Seo JK, Eom JU, Yang HS. 2023. Comparison between Berkshire and crossbreed on meat quality, and investigation of the relationship with fatty acid composition and meat quality. J Anim Sci Technol 65:1081-1093.

Trusell KA, Apple JK, Yancey JWS, Johnson TM, Galloway DL, Stackhouse RJ. 2011. Compositional and instrumental firmness variations within fresh pork bellies. Meat Sci 88:472-480.

Uttaro B, Zawadski S. 2010. Prediction of pork belly fatness from the intact primal cut. Food Control 21:1394-1401.