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ANIMAL

Evaluation of the correlation between the muscle fat ratio of pork belly and pork shoulder butt using computed tomography scan

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Abstract

This study was conducted to find out the correlation between meat quality and muscle fat ratio in pork part meat (pork belly and shoulder butt) using CT (computed tomography) imaging technique. After 24 hours from slaughter, pork loin and belly were individually prepared from the left semiconductors of 26 pigs for CT measurement. The image obtained from CT scans was checked through the picture archiving and communications system (PACS). The volume of muscle and fat in the pork belly and shoulder butt of cross-sectional images taken by CT was estimated using Vitrea workstation version 7. This assemblage was further processed through Vitrea post-processing software to automatically calculate the volumes (Fig. 1). The volumes were measured in milliliters (mL). In addition to volume calculation, a three-dimensional reconstruction of the organ under consideration was generated. Pearson's correlation coefficient was analyzed to evaluate the relationship by region (pork belly, pork shoulder butt), and statistical processing was performed using GraphPad Prism 8. The muscle-fat ratios of pork belly taken by CT was 1 : 0.86, while that of pork shoulder butt was 1 : 0.37. As a result of CT analysis of the correlation coefficient between pork belly and shoulder butt compared to the muscle-fat ratio, the correlation coefficient was 0.5679 (R^2 = 0.3295, $p < 0.01$). CT imaging provided very good estimates of muscle contents in cuts and in the whole carcass.

Keywords: computed tomography, muscle and fat ratio, pork belly, pork shoulder butt

Introduction

In South Korea, since 2007, pig carcass grading standards have been determined by categorizing them into primary meat quantity and secondary meat quality criteria, and then assigning a single grade that combines both meat quantity and quality (KLEI, 2009; Bae et al., 2016). Secondary evaluation is conducted by trained assessors who classify based on appearance criteria (such as fat content and pork belly condition), meat quality criteria (including fat deposition, meat color, meat texture, fat color, and fat content), and defect criteria (such as lesions, fractures, and muscle hemorrhage). However, currently, there isn't a significant difference in pork quality based on grades, and pig carcass grade represents meat quantity rather than meat quality. To address this issue, evaluating pork quality using traditional methods based on physical dissection adds costs, increases manpower demand, consumes time, and may involve occasional subjectivity based on the expertise of evaluators (Monziols et al., 2006; Prieto et al., 2009).

With the recent increase in consumption of grilled pork belly and pork shoulder, there is a growing demand for quality labeling of meat cuts. However, these preferred cuts, pork shoulder butt, and pork belly, are not exposed during grading process, making it difficult for experts to assess meat quality solely by visual inspection.

In recent years, with the advancement in technologies, several non-invasive and non-destructive techniques such as, spectroscopic techniques (e.g., Raman spectroscopy), imaging techniques (including radiography, and thermal imaging), multiplanar imaging techniques (such as magnetic resonance imaging and computed tomography), etc. have been introduced to study composition of carcasses or live animals and assess their quality (Wu et al., 2022). However, MRI (magnetic resonance imaging) has time constraints, and ultrasound is associated with the disadvantage of relatively low accuracy (Sammak et al., 1999). Therefore, CT (computed tomography) is considered to most suitable method to determine the level of muscle and fat content in a carcass.

While studies have been conducted to address these issues by examining the correlation between the entire carcass and the pork belly quality or to confirm the correlation between weight or genetics and the pork belly quality (Duziński et al., 2015; Lee et al., 2018; 2023), there is a noticeable lack of research on the correlation between pork belly and the pork shoulder butt. Therefore, in this review, we aimed to investigate the correlation between the muscle-to-fat ratio of pork belly and pork shoulder butt using CT.

Materials and Methods

Animals, slaughter, and dissection

The present study was conducted on 26 crossbred (Duroc × [Landrace × Large White]) gilt carcasses with an average live weight of 115 kg. The animals were slaughtered following the standard procedures of the Korea Institute for Animal Products Quality Evaluation at a slaughterhouse approved for the humane management and use of animals. The left half carcass was used in this study. At 24 h after slaughter, the pork shoulder butt and pork belly were dissected from the carcass for imaging examination.

Computed tomography

Each of the 26 pork belly and pork shoulder butt were scanned using a 32-detector-row CT scanner (Alexion™, Toshiba, Japan) with following scan parameters: 120 kilovoltage peak (kVp), 150 milliampere-seconds (mAs), 1 mm slice thickness, 0.75 second rotation time, and a 0.938 collimation beam pitch. The acquired CT images displaying a soft tissue window (window level = 40 HU (Hounsfield units), window width = 400 HU) were extracted using commercially available software (Xelis, INFINITT Healthcare Co., Ltd., Korea).

Image & statistical analysis

The image obtained from CT scans was checked through the picture archiving and communications system (PACS). The volume of muscle and fat in the pork belly and shoulder butt of cross-sectional images taken by CT was estimated using Vitrea workstation version 7 (Vital Images, USA). To calculate the muscle and fat content within the pork belly and shoulder butt, areas with the corresponding HU values on the CT scans were primarily identified manually. While the Vitrea software aided with semi-automated detection of contiguous regions exhibiting similar HU values, manual adjustments were frequently made to exclude any undesired areas. These selected regions were aggregated from each slice. Subsequent to this, the gathered data was processed using the Vitrea post-processing software to determine the volumes, which were measured in milliliters (mL). In addition to volume calculations, a three-dimensional reconstruction of the organ of interest was generated. Pearson's correlation coefficient was analyzed to evaluate the relationship by region (pork belly and shoulder butt), and statistical processing was conducted using GraphPad Prism 8 (GraphPad Software, USA).

Results and Discussion

Estimates of muscle and fat contents in the cuts

During the CT scan of the pork tissue (belly and shoulder butt), the absorption rate, which varies depending on muscle and fat density, was represented as a 3D image expressed in HU using reconstruction technology and displayed in Fig. 1 (Font-i-Furnols et al., 2009; Lucas et al., 2017; Xiong et al., 2017). After CT imaging and automated calculation using the Vitrea workstation, the muscle-to-fat ratio for pork belly was 1 : 0.86, and for pork shoulder, it was 1 : 0.37 (Table 1). As a result of CT analysis of the correlation coefficient between pork belly and pork shoulder butt in relation to the muscle-fat ratio, the correlation coefficient was 0.5679 ($R^2 = 0.3295$, $p < 0.01$) (Fig. 2).

Non-invasive methods for assessing tissue composition without cutting the body include CT, MRI, and ultrasound. However, MRI has time constraints and ultrasound has the disadvantage of relatively low accuracy, so CT is considered to be the most appropriate method to determine the level of muscle and fat content in a carcass. CT, an important tool used in medical diagnosis, has gained significance in recent years for understanding the composition of carcasses and various livestock species such as sheep, goats, pigs, cattle, and more (Bunger et al., 2011). Researchers have reported using CT scanning to measure lean percentage and fat content in whole pig bodies and/or carcasses (Horn et al., 1997; Dobrowolski et al., 2004; Romvári et al., 2006). According to Dobrowolski et al. (2004), the CT method is a recommended reference method for determining meat content. Romvári et al. (2006) reported a correlation of 0.97 between muscle mass determined by CT scans and slaughter results measured using traditional methods, as well as a correlation of 0.95 for fat content.

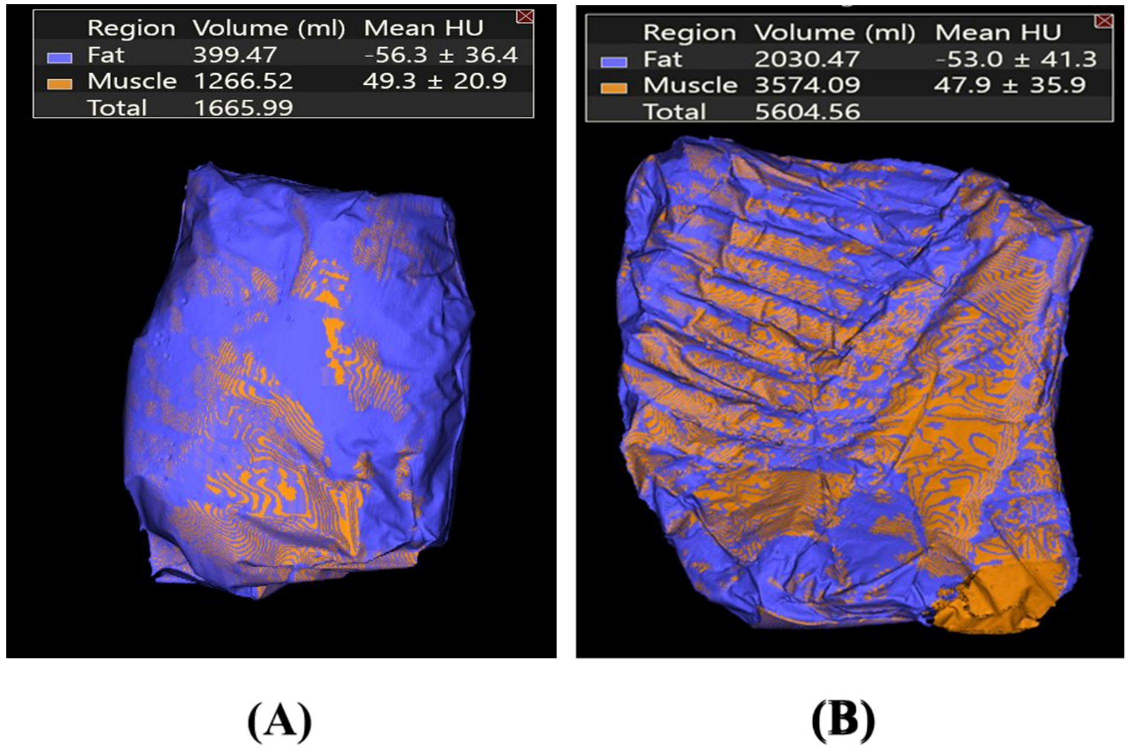

Fig. 1. Example of muscle and fat volume in CT (computed tomography) images of (A) pork shoulder butt and (B) belly analyzed by Vitrea workstation version 7 (blue, fat; orange, muscle). HU, Hounsfield units.

Table 1. Muscle and fat content of pork shoulder butt and belly.

Segmented volume and tissue ratios	Pork shoulder butt	Pork belly
Muscle (mL)	1,378.4	3,165.3
Total fat (mL)	497.5	2,694
Subcutaneous fat (mL)	90.61	1,294.89
Muscle : fat ratio	1 : 0.37	1 : 0.86
Total : subcutaneous fat ratio	1 : 0.13	1 : 0.45

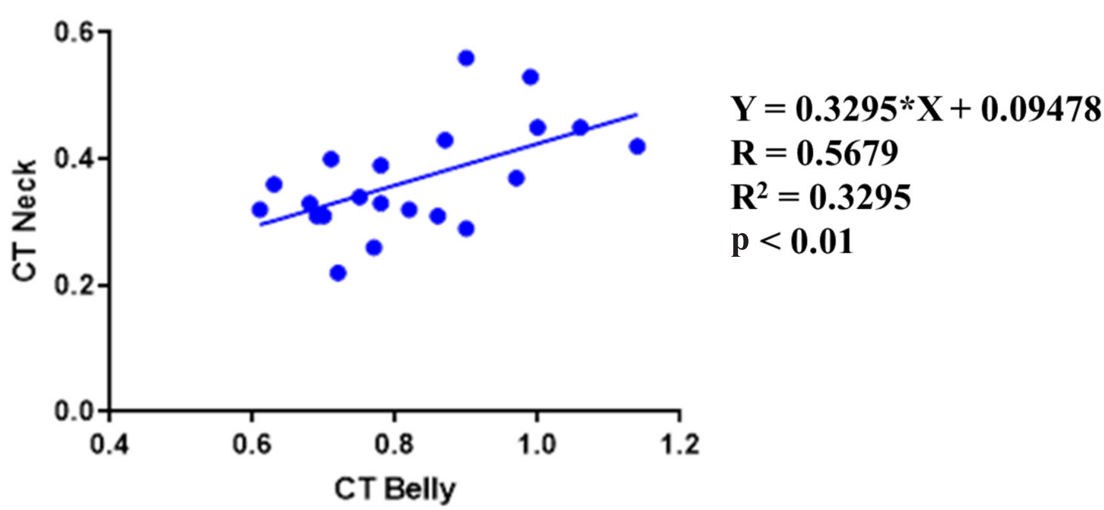

Fig. 2. Correlation between muscle-fat ratio of pork shoulder butt and belly compared through CT (computed tomography).

The application of CT in this study allows for the non-invasive assessment of tissue composition in live animals. However, there are several key considerations that need to be addressed for widespread use. In post-mortem research, tracking over time is essential due to significant physicochemical alterations resulting from slaughter and post-mortem muscle water loss and fat crystallization. Additionally, Trusell et al. (2011) reported significant variations in muscle and fat distribution in pork belly based on anatomical vertebral positions. Hence, estimations of fat content through CT imaging still require improvement, especially with regard to the ratio between muscle and fat.

Conclusion

This study was conducted to investigate the correlation between meat quality and muscle fat content in pork cuts (pork belly and pork shoulder butt) not exposed in the carcass state using CT imaging techniques. The application of CT, as utilized in this study, allows for the non-invasive assessment of tissue composition in half carcass, and as a result, CT images provided very accurate estimates of muscle content. Therefore, the results of this study are expected to provide objective data that can be used as a reference for predicting and grading carcass quality. However, further, more detailed investigations are needed to validate these results.

Conflict of Interests

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

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