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Abstract

With an increase in meat consumption, the need to measure the weight of each primal cut of pork has increased. Recently, automation devices have been used to measure the weight of each primal cut of pork. The objective of this study was to investigate the accuracy of VCS2000, one of the non-invasive pig carcass analyzers. Production levels of 7 primal cuts of 50 pigs were measured with VCS2000. Average error rates between dissected value for each primal cut and VCS2000 measurement values of ham, shoulder picnic, belly, loin, and shoulder blade were around 5%. Average error rates for spare rib and tenderloin were about 10%. Correlation coefficients between the dissected value and the VCS2000 measured value for ham, shoulder picnic, loin, belly, and shoulder blade were high at 0.66 - 0.83. Correlation coefficients of spare rib and tenderloin were low at 0.35 and 0.47. Coefficient of determination of the VCS2000 measured value for each primal cut by regression analysis was 0.77 or more for ham, shoulder picnic, loin, and shoulder blade and 0.63 for belly. Coefficients of determination for spare rib and tenderloin were low at 0.40 and 0.27. In addition, the coefficient of determination of VCS2000 for each primal cut was higher than that of the dissected value for all primal cuts. In conclusion, pig carcass analysis using the VCS2000 has a high reliability for pork cuts with high production levels, but a relatively low reliability for pork cuts with low production levels and high fat levels.

Keywords: primal cut, VCS2000, dissected value, correlation coefficient, determination coefficient

Introduction

With increasing meat consumption in Korea, pork consumption has also increased. Pork production has increased from 891,000 tons in 2016 tons to 1,097,000 tons in 2021 (Statistical office, 2022). As pork consumption increases, the number of pigs raised continues to increase from 10,366,779 in 2016 to 11,216,566 in 2021 (Livestock product grading Statistical yearbook, 2021).

As the amount of pork consumed increases, more consumers want meat with improved quality (Park et al., 2022). In 1992, livestock product grading was conducted. Among livestock product grading systems in Korea, the pig carcass grading system has three grades (grades 1+, 1, and 2) according to carcass weight and backfat thickness. It is mainly classified based on lean meat production. Pig carcass grading has led to improved pork quality, distribution reliability, and reasonable pricing (Choi et al., 2018). In addition, data obtained from carcass grading systems have led to advances in breeding and breeding techniques (Park et al., 2022). However, with recent development of the pig farming industry, the number of pigs being slaughtered is increasing. Currently, large slaughterhouses slaughter 400-500 pig carcasses per hour. Since graders have to grade many pig carcasses, they experience fatigue which can reduce the accuracy of grading (Kim et al., 2021). In addition, since preferred parts of pork differ according to the preference of consumers, it is important to investigate the production volume of each part of pork (Ngapo et al., 2007). Pig carcass grading is performed after slaughter. Then since carcass characteristics (carcass weight and backfat thickness) and meat quality characteristics (meat color, fat color, marbling level) are displayed, the production of primal cut of pig carcasses is unknown until the carcass is trimmed.

Currently, technologies that can automatically analyze pig carcasses in a non-invasive way are being used in livestock farming in developed countries. And the technology makes it possible to know the weights and percentages of pig carcasses, such as the weight of primal cuts and characteristics of primal cuts. A machine that can analyze pig carcasses through a non-invasive technology is called an automatic grading machine judging device (Kim et al., 2017). Different technologies are used in such machines, including x-ray (for DXA) (Soladove et al., 2016), ultrasound (for AutoFom III, Ultrafom 300, CVT-2) (Fortin et al., 2004), magnetic resonance imaging (Collewet et al., 2005), computed tomography (Picouet et al., 2010), and VCS2000 using photographic technology (Kim et al., 2021). These machines are used in Europe and North America.

Among them, VCS2000 developed by E+V Technology GmbH (Germany) was launched in the early 2000s as an automatic grading machine judgment device using photographic technology. VCS2000 is used in three countries, Belgium, Spain and France. Its use is gradually increasing (Kim, 2023).

According to Ngapo et al. (2007), Canada, Germany, Spain, the Netherlands, and the United States prefer lean meat with less marbling and lower fat content. On the other hand, Koreans traditionally preferred to grill meat (Choe et al., 2015; Choi et al., 2019). As a result, pork belly or shoulder blade, which has a lot of fat, is the most preferred cut among different pork cuts. Overseas countries have already used automatic grading machine judgment devices to analyze production volume by primal cuts of pig carcass along with the grading system of each country (Park et al., 2022). The use of such a mechanical device enables rapid feedback on lean meat content, fat content, and carcass characteristics of pork, making it possible to sort carcasses before they enter the refrigerating chamber so that slaughter production efficiency can be increased (Choi et al., 2018).

Therefore, the purpose of this study was to determine the accuracy of VCS200, one of the non-invasive carcass analyzers that could measure the production of pig carcasses by part. Measured values of VCS2000 were also compared with measured values directly trimmed by experts.

Materials and Methods

Animals

Pigs used for calibration were LYD (Landrace × Yorkshire, F1 × Duroc) crossbred species. Pigs were slaughtered from May 19, 2022 to May 20, 2022 at the Bukyung Pig Livestock Products Market (Juchon-myeon, Gimhae, Gyeongsangnam-do) in Gimhae, Gyeongsangnam-do, Korea in accordance with the Livestock Products Sanitation Control Act (Livestock Sanitation Control Act, 2021 revision). A total of 50 pigs (30 gilts and 20 barrows) were collected for the calibration test. Pigs for the calibration test had carcass weights between 76 kg and 100 kg in accordance with the Livestock Products Sanitation Management Act (pork part separation standard) (Livestock Sanitation Management Act, 2021 revision). A total of 7 primal cuts (Shoulder blade, Shoulder picnic, Belly, Loin, Spare rib, Tenderloin, Ham) were weighed with the VCS2000. They were then directly dissected and weighed.

Measurement with VCS2000

A VCS2000 equipment (E+V Technology GmbH, Germany) consists of a total of three cameras: one black and white camera and two-color cameras. It was used for measured after pig carcass was divided into two parts. The VCS2000 equipment consists of a total of 10 items such as lighting device, background device, carcass guide, carcass holder, control box, vision program, and computer spare parts. First, the bisected pig carcass was fixed to the carcass holder and primarily photographed with a black and white camera. Afterwards, through the process of filming with two color cameras, captured images were input into a computer and analyzed. Weights or percentages of seven primal cuts are presented.

Error rate

The error rate was investigated to measure the ratio of the error between the dissected value and the VCS2000 measured value. The average error rate between VCS2000 measured value and the dissected value was obtained as follows: $\sqrt{\sum (X_{\text{dissected value}} - X_{\text{VCS2000}})^2/50}$. The dissected value error rate was obtained by dividing the average error by the average dissected value for each part and multiplying by 100 [(Error mean/mean of dissected value) Ｘ100 (%)]. The VCS2000 error rate was obtained by dividing the average error by the average VCS2000 measurement per site and multiplying by 100 [(Error mean / mean of measured value by VCS000) Ｘ100 (%).

Statistical Analysis

Descriptive statistics (Maximum, Minimum, Mean, Median, Mode, Kurtosis, Skewness) were obtained to compare VCS2000 measured values with dissected values. The homogeneity of variance was identified through the F-test. A t-test was performed for Means and Standard deviation. Pearson's correlation coefficient was obtained to analyze the correlation between the VCS2000 measured value and the dissected value. A single regression analysis was performed with carcass weight as the dependent variable and the weight of each part as the independent variable. All these statistical processes were performed using the SPSS program version 26.0 (SPSS Inc., Chicago, IL, USA).

Results and Discussion

To investigate the accuracy of VCS2000, 50 pigs were used to compare the minimum, maximum, mode, median, and average of the VCS2000 measured values and the dissected values. After measuring the production of each part of the pig carcass with the VCS2000, experts trimmed and weighed each part. Primal cuts of pig carcass were measured by dividing them into the following seven main parts of the pig carcass: ham, shoulder blade, belly, loin, shoulder picnic, spare rib, and tenderloin. The minimum, maximum, mode, median, and mean of these seven primal cuts were obtained and compared with the VCS2000 measured values and the dissected values (Table 1). The production of each primal cut was highest in the order of ham, belly, shoulder picnic, loin, shoulder blade, rib, and tenderloin in both the VCS2000 measured values and the dissected values ($p < 0.01$). As a result of investigating seasonal production levels of six primal cuts (ham, shoulder picnic, loin, shoulder blade, spare rib, and tenderloin) of LYD pig, production level was the highest in the order of ham, shoulder picnic, loin, shoulder blade, spare rib, and tenderloin (Choi et al., 2019). In previous surveys on the production of seven primal cuts by pig carcass grading system in Korea, the production by primal cut was in the order of ham, belly, shoulder picnic, loin, shoulder blade, spare rib, and tenderloin (Lim et al., 2022; Park et al., 2022), consistent with results of the present study.

To investigate distributions of the VCS2000 measured values and the dissected values of the seven primal cuts of pork, descriptive statistics of the VCS2000 measured values and measured values were compared with a plot box (Figure 1). Among these seven primal cuts, descriptive statistics of the VCS2000 measured values and the dissected values of ham, belly, shoulder picnic, loin, and shoulder blade were similar, which produced relatively large amounts. However, descriptive statistics of the VCS2000 measured values and the dissected values of spare rib and tenderloin had relatively smaller amounts than those of other primal cuts, showing a large difference (Figure 1 & Table 1).

Error rates between the VCS2000 measured values and the dissected values are shown in Table 2. The error rate was calculated as described in Materials and Methods. The average error between the VCS2000 measured value and the dissected value was less than 1 kg for all primal parts except for the belly (Table 2). Error rates for ham, shoulder picnic, and shoulder blade were all less than 5%. They were about 6% for belly and loin (Table 2). Branscheid et al. (2000) have shown similar results. They reported that the difference between the VCS2000 measured value and the dissected value was small for the ham. Belly and Loin have high amounts of fat. Belly is composed of about 50% fat and loin has about 33% fat (Uttaro & Zawadski, 2010; Soladoye et al., 2015; Choi et al., 2019). Furnols et al. (2009) have suggested that a larger amount of fat can make it more difficult to dissect, leading to a greater error. It could be seen that the error rate of the fat-rich part among pork parts was relatively high. Error rates for spare rib and tenderloin were the highest at about 10% or more (Table 2). Spare rib and tenderloin were parts with the least amount of production among the seven primal cuts (Table 1). The error rate increased as the production amount decreased (Table 2).

Correlations between the VCS2000 measured values and the dissected values were analyzed. Results are shown in Figure 2 and Table 3. The VCS2000 measured value was set as the x-axis and the dissected value was set as the y-axis. A positive correlation was shown between these two values. The higher the correlation coefficient, the denser the sample was in the correlation expression (Figure 2 & Table 3). The R^2 value was said to have adequate accuracy in $0.8 \geq R^2 \geq 0.6$, and low accuracy in $0.6 > R^2$ (Bucchianico, 2008). In the case of Ham, Shoulder Picnic, and Loin, the coefficients of determination all showed good values of 0.6 or higher. Shoulder blade and belly showed more than 0.4, and spare rib and tenderloin showed very low values of 0.1183 and 0.2226, respectively. In the case of spare rib and tenderloin, as shown in Table 2, the error rate is large and a small amount appears in the part attached to the inside of the belly and shoulder blade, so it is considered that the size of error during trimming has increased. In fact, as a result of calculating the Correlation of Variation ($CV=\sigma/\mu$), the difference between each VCS2000 measured value and the dissected value was 2% and 3%, which was the same or higher than that of other parts. (Ham 1%, shoulder picnic 2%, Loin 2%). The difference between the VCS2000 measured values and the dissected values of Shoulder blade and Belly showed a value of 2%. The reason why the coefficient of determination showed appropriate accuracy is thought to be the difference that appeared during trimming because Shoulder blade and Belly are fat-rich parts. According to the correlation coefficient, the correlation level was defined (weak correlation, correlation coefficient in the range of 0.10-0.39; medium correlation, correlation coefficient in the range of 0.40-0.69; and strong correlation, correlation coefficient in the range of 0.70-0.89) (Schober et al., 2018). Correlation coefficients for ham, shoulder picnic, and loin were 0.77 - 0.83, indicating high correlations between the VCS2000 measured values and the dissected values. Correlation coefficients for belly and shoulder blade were 0.67 and 0.66, respectively, indicating medium correlations between the VCS2000 measured values and the dissected values. Correlation coefficients for spare rib and tenderloin with low production levels were 0.35 and 0.47, respectively, showing relatively low correlations between the VCS2000 measured values and the dissected values, unlike other parts (Table 3). Lohumid et al. (2018) have also reported that prediction errors for tenderloin and spare rib are higher than all except for tenderloin and spare rib. The weight of tenderloin was 0.38~0.69 kg, which was a small amount. It is said that the difference in experts in the dissection process has a great influence on the results. In the case of tenderloin, the measurement error exceeded 50%. However, this value was considered valid due to a significant *p*-value (Branscheid et al., 2009). For the overall correlation of the seven primal cuts, the correlation coefficient between the VCS2000 measured value and the dissected value was 0.927 ($p < 0.01$), which was the highest value of Coefficient for the VCS2000 measured value and the dissected value. Although the overall correlation analysis included results for spare rib and tenderloin, the correlation between the VCS2000 measured value and the dissected value of carcass was high.

A single regression analysis was conducted to investigate the relationship between carcass weight and weight by 7 primal cuts of the dissected values and the VCS2000 measured values. In the regression analysis, the dependent variable was carcass weight, and the independent variable was weight of each primal cut. The coefficient of determination of the dissected value was high in the order of shoulder picnic, ham, shoulder blade, loin, belly, spare rib, and tenderloin. The

VCS2000 measurement value had a high coefficient of determination in the order of shoulder picnic, ham, loin, shoulder blade, belly, spare rib, and tenderloin. (Table 4). In the study of Fortin et al. (2004), when the production of five primal cuts of pig carcass was predicted using three types of ultrasound instruments, the coefficient of determination was high in the order of ham, loin, shoulder picnic, shoulder blade, and belly. These results showed the same tendency except for the shoulder picnic. Coefficients of determination of all five primal cuts were 0.6 or higher, showing similar results to measured values of the VCS2000 in this experiment. Parts with a lot of fat, especially those with low production levels, showed lower coefficients of determination than other parts. Coefficients of determination of belly, spare rib, and tenderloin were lower for both the dissected values and the VCS2000 measured values. Parts with a lot of fat are difficult to dissect, leading to large errors (Furnols et al., 2009). It is considered that parts with low production levels tend to be prone to errors in detection accuracy of machines or differences in skill levels between workers when dissecting carcasses. Comparing the coefficient of determination of the dissected value with the VCS2000 measured value, the coefficient of determination of the dissected value was lower than the VCS2000 measured value for all 7 primal cuts (Table 4). In the future, a more careful experiment is needed to determine whether these results are due to expert's mistake in the process of trimming primal cuts or whether the VCS2000 has a high precision.

In this experiment, in order to investigate the accuracy of VCS2000, a carcass analyzer, VCS2000 measured values for seven primal cuts of pig carcasses were compared with their actual values. Error rates were around 5% for five primal cuts, excluding spare rib and tenderloin. The correlation coefficient was 0.66 or higher, showing a high correlation. The coefficient of determination was larger for VCS2000 measured values than for dissected values. Therefore, pig carcass analysis using VCS2000 shows a high reliability for areas with high production levels and a relatively low reliability for areas with low production and high fat levels.

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Tables and Figures

Table 1. Descriptive statistical of value measured by VCS2000 and the dissected value (kg)

	Min		Max		Mode		Median		Mean	
	Dissected	VCS[1]	Dissected	VCS	Dissected	VCS	Dissected	VCS	Dissected	VCS
Ham	15.74	17.11	22.16	23.11	16.78	17.34	18.52	19.21	18.44	19.34
Shoulder picnic	10.12	9.73	13.70	12.80	11.86	11.02	11.64	11.40	11.72	11.42
Belly	11.22	13.24	20.08	19.80	14.30	16.19	16.12	17.07	16.24	17.04
Loin	7.86	8.19	11.42	11.65	9.02	9.81	9.51	10.04	9.54	10.10
Shoulder blade	4.78	5.01	7.34	6.48	5.80	5.89	5.79	5.85	5.79	5.78
Spare rib	2.82	3.21	4.08	4.41	3.22	3.65	3.50	3.69	3.48	3.74
Tenderloin	0.76	0.92	1.20	1.32	0.88	1.06	0.95	1.08	0.95	1.09

[1]VCS2000. n=50.

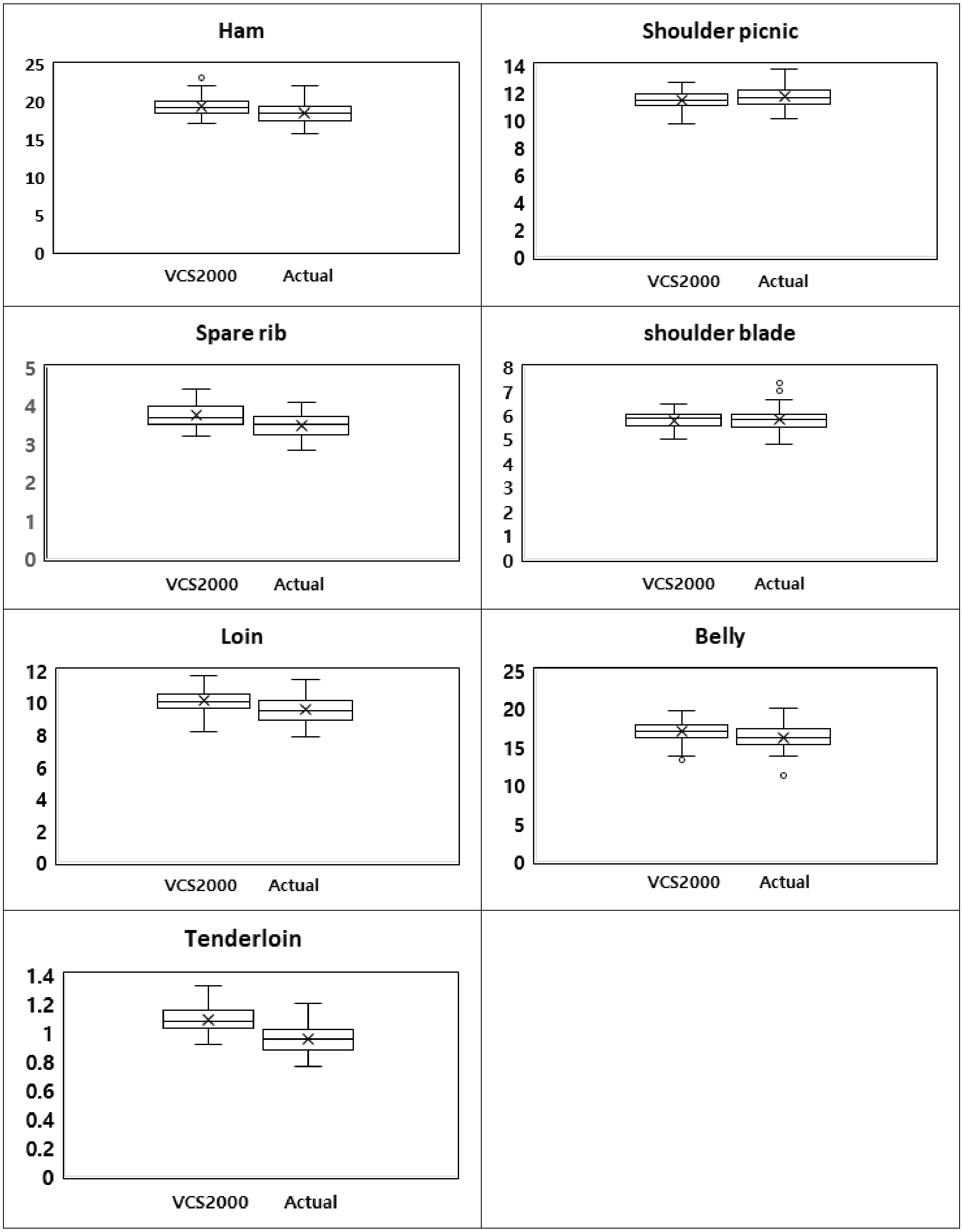


Figure 1. Plot box for each 7 primal cuts of the VCS2000 measured value and dissected value before trimming. VCS2000; VCS2000 measured value. Dissected: Dissected value. N=50.

Table 2. Error rate between VCS2000 Measured Values and dissected value

	Error Mean (kg)[1]	Error Rate(%)

		Dissected[2]	VCS2000[3]
Ham	0.98 ± 0.65	5.3	5.1
Shoulder picnic	0.42 ± 0.37	3.6	3.7
Belly	1.09 ± 0.94	6.7	6.4
Loin	0.64 ± 0.43	6.7	6.3
Shoulder blade	0.28 ± 0.24	4.8	4.8
Spare rib	0.36 ± 0.26	10.3	9.6
Tenderloin	0.15 ± 0.09	15.8	13.8

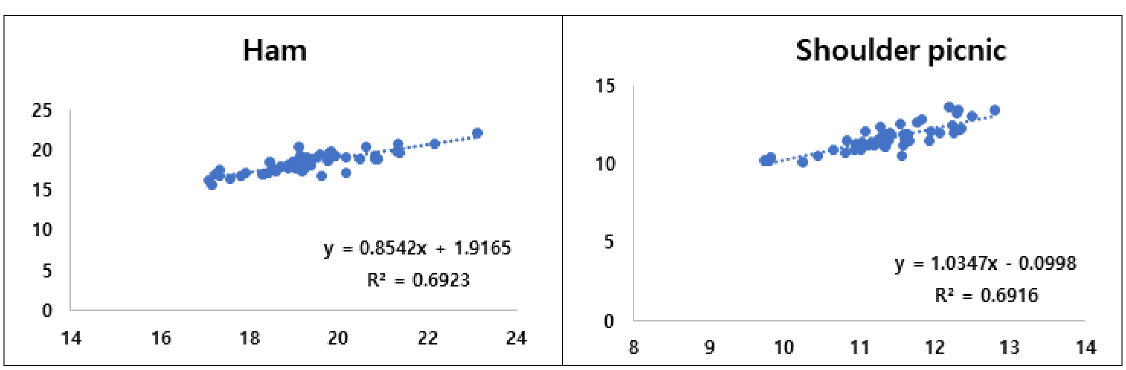
[1]; $\sqrt{\sum(X_{dissected} - X_{VCS2000})^2/50}$. [2]; (Error/dissected value) ☓100 (%). [3]; (Error/VCS2000) ☓100 (%). Error mean ± standard deviation. n=50.

Table 3. Correlation coefficient between VCS2000 measured value and dissected value

	Correlation coefficient

Ham	0.8319**
Shoulder picnic	0.8316**
Belly	0.6708**
Loin	0.7747**
Shoulder blade	0.6606**
Spare rib	0.3463*
Tenderloin	0.4730**
Total	0.9270**

**: $p<0.01$. *: $p<0.05$. n=50.



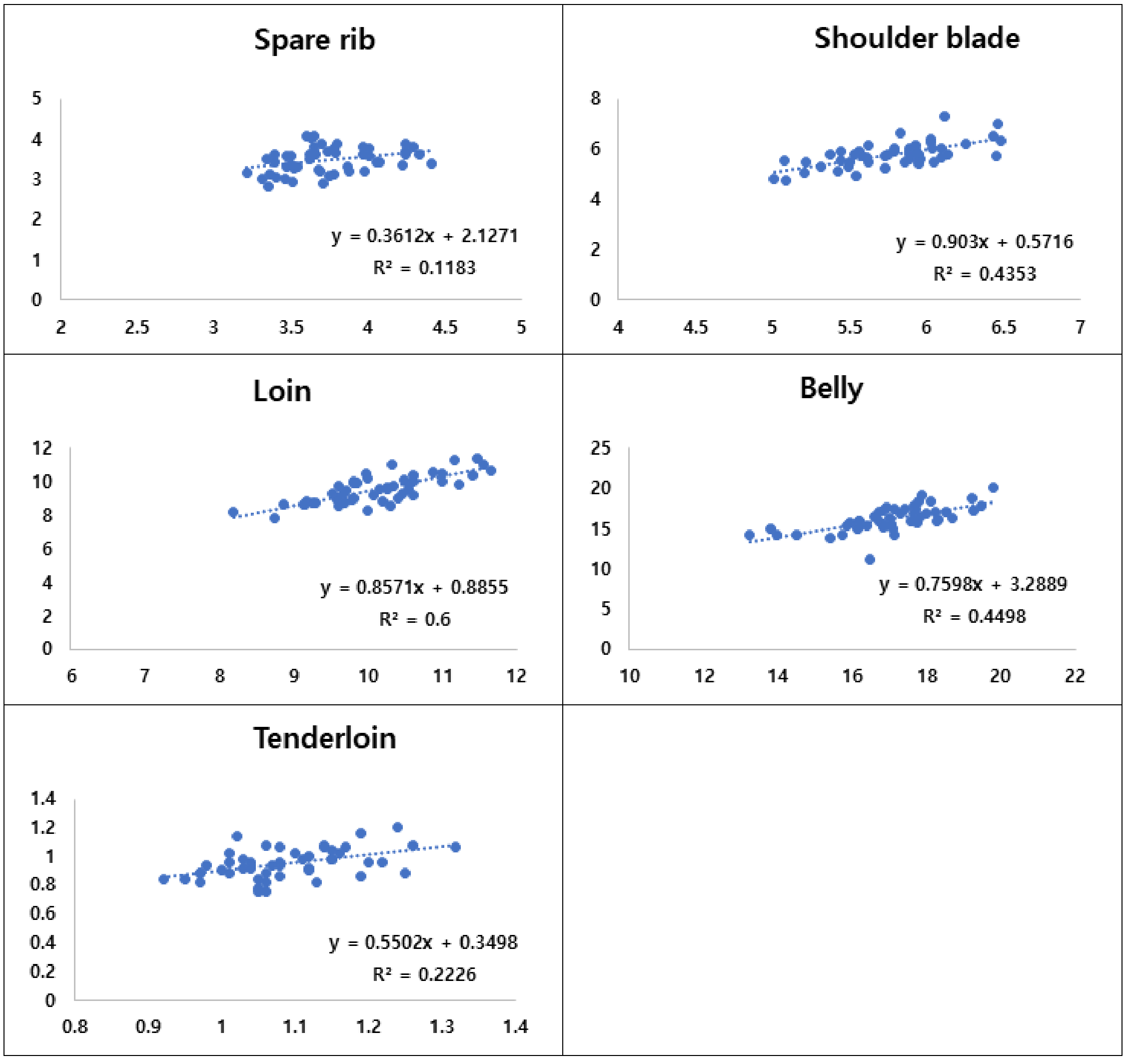


Figure 2. Correlation between VCS2000 measured values and dissected values of 7 primal cuts of pork. Y axis: Dissected value, x axis: VCS2000 measured value. n=50

Table 4. Coefficient of determination of 7 primal cuts

	Coefficient of determination (r^2)	
	Dissected	VCS2000
Ham	0.6015	0.7949
Shoulder picnic	0.7619	0.8657
Belly	0.4108	0.6327

Loin	0.4737	0.7755
Shoulder blade	0.5794	0.7717
Spare rib	0.3236	0.4018
Tenderloin	0.0968	0.2726

Dependent variable: Carcass weight(kg). Independent variable: each weight of 7 primal cuts (kg).

n=50