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Relationship between rib fat thickness and carcass price among different carcass weight groups in Korean native cattle

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Abstract: The study assessed the relationship between rib fat thickness and carcass price among different carcass weight groups in Korean native cattle (Hanwoo), taking into account changes in the beef grading system. Data from 8 926 Hanwoo steers, with an average age of 30.6 ± 1.88 months and slaughtered between 2017 and 2019, were analysed. The variables considered included rib fat thickness, carcass weight, eye muscle area, marbling score, and carcass price. Steers were categorised into eight carcass weight groups ranging from 250 kg to 650 kg in the original system, rib fat thickness consistently had a negative impact on carcass price, with partial coefficients of rib fat thickness on carcass price ranging from −1.96 to −46.5 depending on the carcass weight groups. Conversely, in the revised system, the impact of rib fat thickness varied from negative to positive, turning positive at the 450 kg carcass weight group. These findings may guide decision-making in beef cattle production and feeding strategies under the revised grading system.

Keywords: carcass price; carcass trait; Hanwoo steers; partial regression

The carcass price (CRP) of beef cattle, which is determined by yield and meat quality grades, significantly influences the income of farmers (Kim et al. 2010a; Lee et al. 2011b). Key determinants of carcass grades include rib fat thickness (RF) and carcass weight (CWT) for yield grade, as well as marbling score (MSC) for quality grade within the Korean beef grading system (Gajaweera et al. 2020). Korean consumers prefer beef with high marbling, leading to a beef grading system that has historically

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focused more on meat quality rather than quantity (Park et al. 2018). However, this emphasis on marbling has led to increased production costs, reduced profit margins for producers, and greater environmental impacts, often due to the extended feeding periods needed to achieve greater levels of marbling (Moon et al. 2003). Additionally, since the year 2011, a decrease in Hanwoo beef prices, stemming from increased slaughter rates and beef imports, has reduced the price influence of meat quality. The rising frequency of high-quality meat grades has also lessened the discriminative ability of the MSC (Kim et al. 2010a), while the importance of carcass yield has increased due to a reduction in Hanwoo supply influenced by Korean national policy. In response, the Korean government has revised beef grading criteria to moderate meat quality standards and to formulate carcass yield equations for different genders including Hanwoo and other beef cattle (MAFRA 2019).

Prior research indicates that RF negatively impacts auction prices and CRP in Hanwoo under the original grading system (Kim et al. 2010b; Lee et al. 2011a; Kong et al. 2016). Yet, under the revised grading system, CWT is considered a positive factor in the yield index calculation, and the MSC criteria for 1++ meat quality have been made less stringent (Kim et al. 2020). Given the positive correlation between RF, CWT, and MSC (Garcia et al. 2008; Lee et al. 2011a), examining the impact of RF on yield grades and CRP under the new grading system is crucial. Although the relationship between CRP and MSC has been well-studied (Lee et al. 2012; Kong et al. 2016), there is a lack of research on the relationship between RF and CRP.

CRP is calculated by multiplying CWT by the auction price; thus, to precisely understand the impact of RF, it is necessary to analyse it using partial regression across different CWT categories. Previous investigations into the influence of carcass traits on CRP in Hanwoo have employed partial regression analysis (Kim et al. 2010; Alam et al. 2013). The regression coefficient, which provides a quantitative measure of the economic value of each trait, is significant for understanding the impact of RF on CRP when considering other variables (Kim et al. 2010). This study aims to examine the partial regression coefficient of RF on CRP across a range of CWT groups under both the original and the revised grading systems.

MATERIAL AND METHODS

Data set

Data were collected from a total of 8 926 Hanwoo steers with an average age of 30.6 ± 1.88 month, raised in 2 572 farms located in 16 regions of Korea, and slaughtered between 2017 and 2019. The major carcass traits for the Korean beef industry are CWT, RF, eye muscle area (EMA), and MSC (Lee et al. 2014; Gajaweera et al. 2020). We obtained the data on those traits from the Korea Institute for Animal Products Quality Evaluation (KAPE). The quality and quantity of beef carcasses are graded into different yield grades (A, B, and C) and quality grades (1++, 1+, 1, 2, and 3) (Gajaweera et al. 2020). Yield grades were determined based on the original (MAFRA 2013; Chung et al. 2018) and newly revised grading system (KAPE 2019; MAFRA 2019) (Equations 1 and 2).

$$\text{YI\_original} = 68.184 - (0.625 \times \text{RF}) + (0.130 \times \text{EMA}) - (0.024 \times \text{CWT}) + 3.23 \quad (1)$$

(A grade ≥ 67.20; B grade ≥ 63.30 and < 67.20; C grade < 63.30)

$$\text{YI\_revised} = [11.063\,98 - (1.25149 \times \text{RF}) + (0.28293 \times \text{EMA}) + (0.56781 \times \text{CWT})]/\text{CWT} \times 100 \quad (2)$$

(A grade ≥ 62.52; B grade ≥ 60.40 and < 62.52; C grade < 60.40)

where:

YI_original – yield index by original grading criteria;
YI_revised – yield index for steer by newly revised grading criteria;
RF – rib fat thickness (mm);
EMA – eye muscle area (cm^2);
CWT – cold carcass weight (kg).

The quality grade is determined by the MSC (1 = devoid, 9 = abundant). Following the nine scale Korean beef marbling standard, quality grade classified by grades 1++, 1+, 1, 2, and 3 (MAFRA 2019). We exclusively used MSC due to its disproportionate impact on meat quality compared to fat colour, texture, and maturity (Cho et al. 2020). The previous study demonstrated the fact that MSC was the most significant determinant of quality grade and there was a little difference in meat colour, fat

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Table 1. Descriptive statistics of the raw data (n = 8 926) of carcass traits and prices

Traits	Mean	SD	Minimum	Median	Maximum
Carcass weight (CWT), kg	442.0	50.5	252.0	442.0	632.0
Eye muscle area (EMA), cm^2	96.1	11.8	43.0	95.0	155.0
Rib fat thickness (RF), mm	14.2	4.50	3.00	14.0	30.0
Marbling score (MSC)	6.18	1.80	2.00	6.00	9.00
Auction price					
Korean won (KRW)/kg CWT	19 425	2 022	14 249	19 990	22 465
US Dollar[1] (USD)/kg CWT	14.94	1.56	10.96	15.38	17.28
Carcass price[2] (CRP)					
1 000 Korean won (KRW)	8 597	1 399	3 648	8 665	13 491
US Dollar[1] (USD)	6 613	1 076	2 806	6 665	10 378

[1]1 300 KRW is approximately equivalent to USD 1.00; [2]Carcass price = carcass weight × auction price
SD = standard deviation

colour, and texture when MSC varied from 1 to 9 (Lee et al. 2012). The CRP (1 000 Korean won; 1 000 KRW) was calculated by multiplying CWT (kg) and auction price (KRW/kg; 1 300 KRW is approximately equivalent to USD 1.00) which was determined by a free auction that depends on yield and quality grades (Choy et al. 2012; MAFRA 2019). The descriptive statistics of raw data are shown in Table 1. The CWT, EMA, RF, MSC, and CRP were used as variables.

Data classification

Hanwoo steers were divided into eight groups according to their CWTs. The eight groups were organised as following: 250~300 kg, 301~350 kg, 351~400 kg, 401~450 kg, 451~500 kg, 501~550 kg, 551~600 kg, and 601~650 kg.

Data analysis

Detecting multicollinearity. Multicollinearity refers to significant linear correlations among the independent variables, which can lead to erroneous regression analysis results (Shrestha 2020). To examine the presence of multicollinearity among the variables in this study, we utilised the variance inflation factor (VIF) method. The VIF values for RF, CWT, EMA, and MSC were 1.17, 1.61, 1.74, and 1.31, respectively. These VIF values fall within the range of $1 < \text{VIF} < 5$, suggesting only moderate correlations among the variables and confirming the absence of significant multicollinearity issues. Based on these findings, we proceeded with the further analysis.

Modelling

This study used partial regression analysis to analyse the contribution of RF on CRP (Equation 3).

$$Y = a + b^1 \text{RF} + b^2 \text{CWT} + b^3 \text{EMA} + b^4 \text{MSC} + e \quad (3)$$

where:
Y – carcass price (KRW, Korean won);
RF – rib fat thickness (mm);
CWT – carcass weight (kg);
EMA – eye muscle area (cm^2);
MSC – marbling score;
e – residual error.

Thus, the dependent variable Y is the CRP; the carcass traits (RF, CWT, EMA, and MSC) are the independent variables; b^1, b^2, b^3, and b^4 are the partial regression coefficients of each trait. The partial regression coefficient b^1 was the amount of response of CRP according to change of RF under other independent variables (CWT, EMA, and MSC) constantly fixed (Alam et al. 2013). Thus, the b1 values was investigated in each CWT group and all the statistical analyses were performed using the R statistics software application (v3.5.3) (R Core team 2016). Statistical significance was determined by the analysis of variance (ANOVA) procedure, followedby mean separation using Duncan's test.

RESULTS AND DISCUSSION

Figure 1 shows the comparison of the means of variables grouping by the CWT using a boxplot. The mean of RF, EMA, and MSC significantly increased proportionally to CWT. This result is consistent with a previous study suggesting that RF, EMA, and MSC of Hanwoo steers increase as CWT increases (Moon et al. 2006).

When comparing the yield grades from the original (Figure 2A) to the revised system (Figure 2B), we observe that in the original system, the highest yield grade, A, decreases linearly with increasing CWT, notably declining from 75% in the 250–300 kg group to 3% in the 550–600 kg group. In contrast, the revised system exhibits a less steep decrease for grade A, suggesting that heavier carcasses are not penalised as heavily as they were under the original system. The appearance rates of yield grades B and C show distinct patterns between the two grading systems. For grade B in the original system, there is an initial rise peaking at the 400–450 kg group, followed by a sharp decline. In the revised system, however, grade B consistently increases with CWT. The frequency of grade C in the original system steadily rises with increasing CWT, whereas in the revised system, it increases up to the 450–500 kg group before declining. These observations indicate that carcasses are more likely to be assigned a yield grade of B rather than C at higher weights under the revised system. Cho et al. (2020) reported that the same carcass traits could result in a slightly higher meat quantity grade under the revised grading system compared to the current system.

In terms of quality grades, the frequency of the highest quality grade, 1++, increases with CWT in both systems (Figure 2C,D); however, the rise is more pronounced under the revised system. This could be attributed to the revised system having more lenient criteria for higher quality grades, leading to an increase in 1++ grade meat (Kim et al. 2020). The appearance rate of grade 1+ peaks in the middle CWT groups before declining in both systems, though it peaks at a lower CWT group and starts declining sooner in the revised system. The lower quality grades, 1 and 2, show a decrease with increasing CWT in both systems, with a more pronounced decrease in the revised system. This trend indicates a shift in grading criteria, where heavier carcasses are more likely to receive higher quality grades under the revised system.

These findings align with previous research, which has linked higher quality grades with increased CWT in Hanwoo (Park et al. 2002; Moon et al. 2006). Moon et al. (2006) noted that higher quality grades were associated with heavier carcasses characterised by thicker RF, larger EMA, and a higher MSC. These grading patterns suggest that the revised system may be less stringent with higher CWTs, thus favouring heavier carcasses for classification as higher yields in grade B rather than grade C, and increasing the number of 1++ grades.

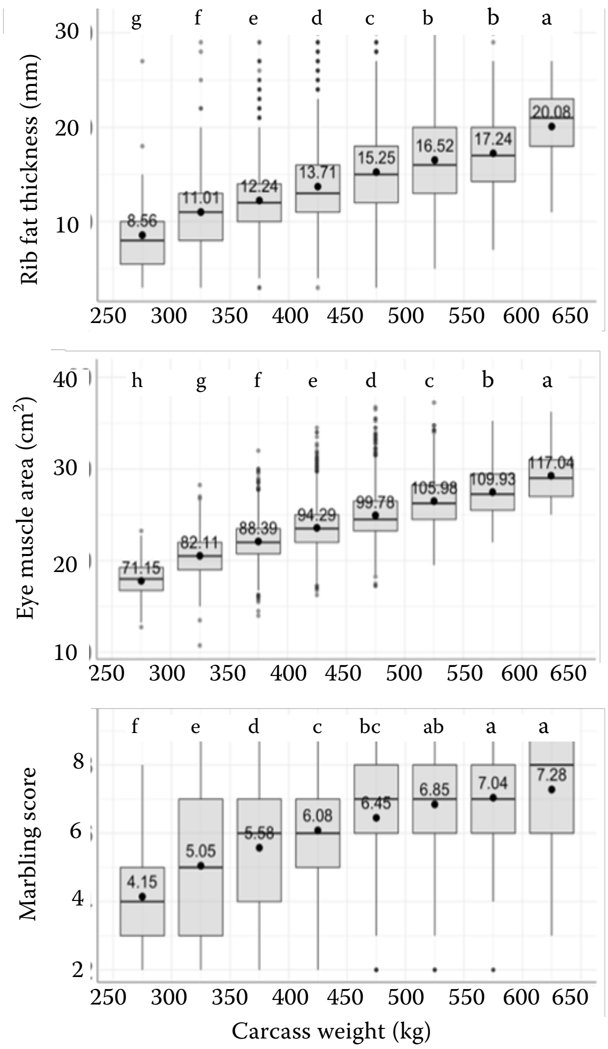

Figure 1. Comparison of the means of the rib fat thickness, eye muscle area, and marbling score grouping by the carcass weight using boxplot

Boxplots represent the mean (•), median, interquartile range, and outliers of individual variables. Different alphabets on the top indicate that the group mean is different ($P < 0.05$)

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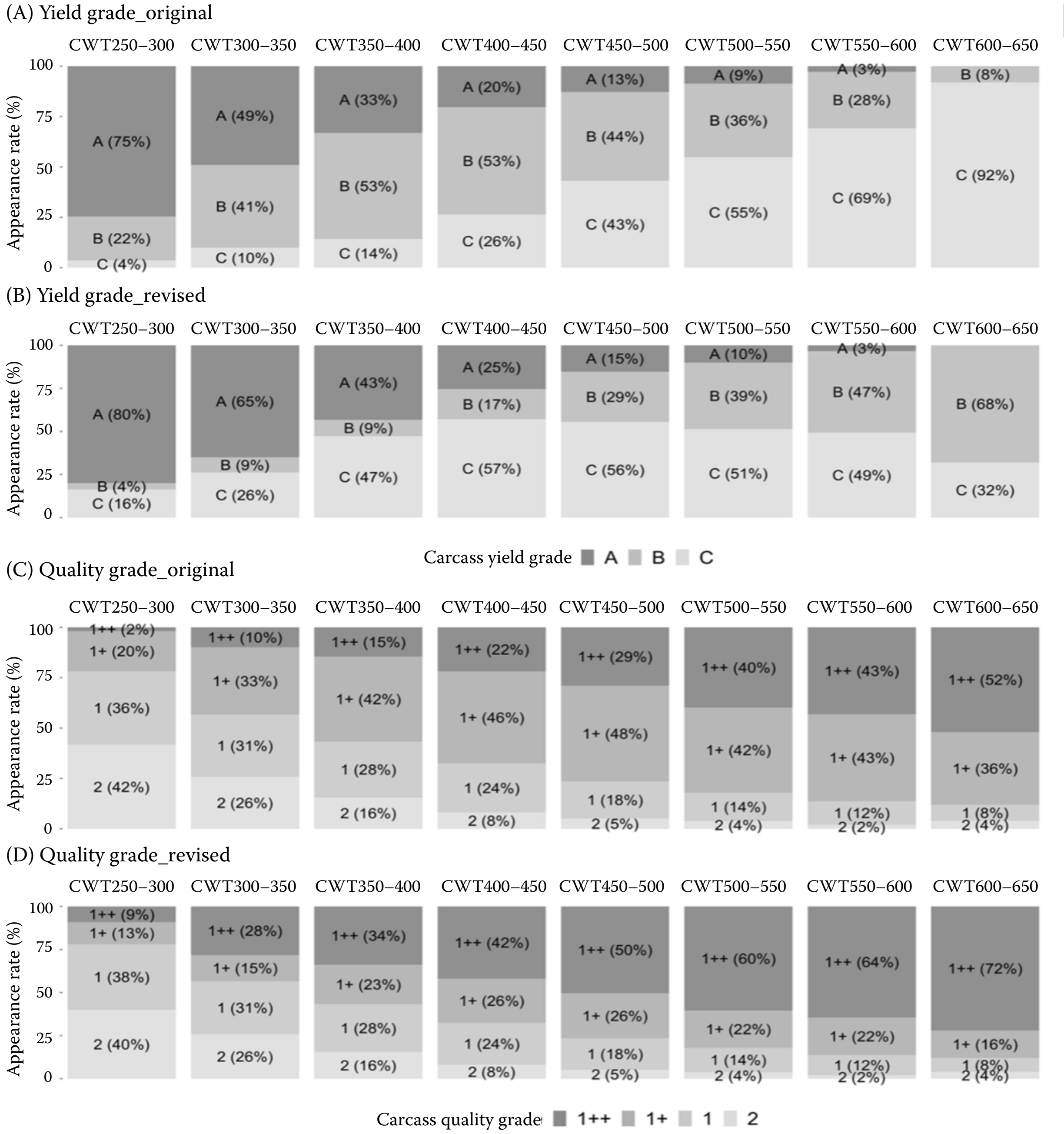

Figure 2. The appearance rate of yield and quality grade of carcasses determined by the original and revised grading system according to different carcass weight groups

Numbers in the bar indicate the yield grade (A, B, or C) and quality grade (1++, 1+, 1, or 2) with their portions in percentage

Figure 3 presents the partial regression coefficients of RF on CRP across different CWT groups in both the original and revised grading systems. In the original system, the coefficients are consistently negative across all CWT groups (Figure 3A), indicating that an additional unit of RF is associated with a decrease in CRP, particularly noticeable in the 400–450 kg CWT group. This is in line with previous studies that have identified a negative relationship between RF and CRP (Kim et al. 2010; Lee et al. 2011a; Kong et al. 2016). In contrast, the revised grading system illustrates a significant change where RF shows a negative impact on CRP in the 250–450 kg CWT group, and

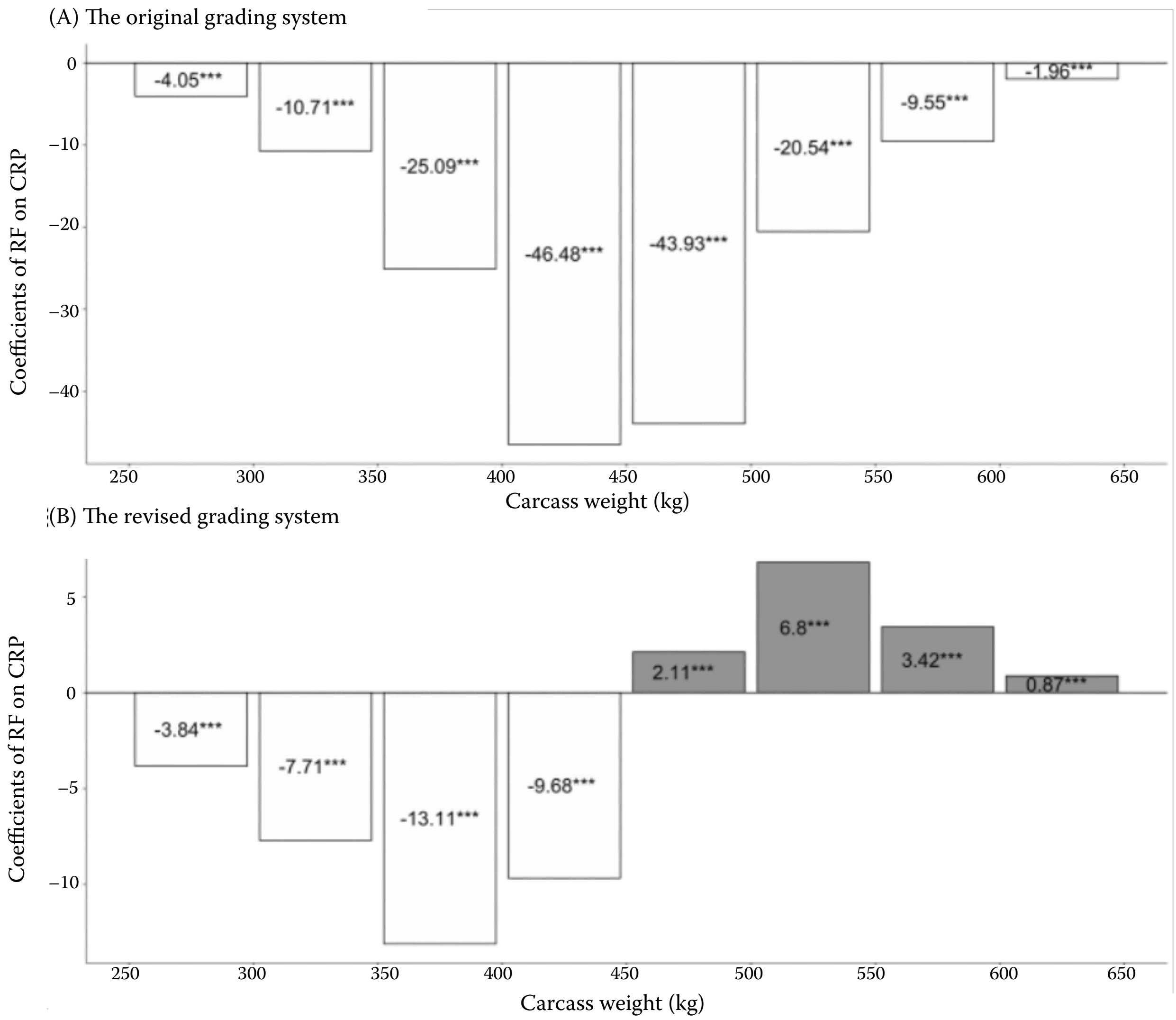

Figure 3. Partial regression coefficients of rib fat thickness (RF) on carcass price (CRP) according to different carcass weight groups in (A) the original and (B) revised grading system
***$P < 0.001$

this relationship turns positive in the 450–650 kg CWT group (Figure 3B). This suggests that for carcasses weighing more than 450 kg, an increase in RF correlates with an increase in CRP, implying a positive economic value for thicker RF at higher carcass weights. The shift reflects the acknowledgment by the revised system of RF as a positive contributor to meat quality, which gains importance as carcass weight exceeds 450 kg. Studies report that RF has a positive influence on meat quality grades, with heavier carcasses that exhibit thicker RF and higher MSC expected to yield higher quality grades (Lorenzen et al. 1993; Moon et al. 2006). Thus, a partial regression coefficient value of 6.80 KRW in the 500–550 kg CWT group suggests that each unit increase in RF adds 6 800 KRW to the CRP, holding other variables constant.

The findings suggest that the original grading system might have inadvertently encouraged practices such as extended feeding periods and overfeeding to achieve higher marbling at the expense of yield. This could have led to increased feed and production costs, ultimately impacting farm profitability negatively (Moon et al. 2003). In contrast, the revised system appears to be more balanced, potentially enabling more efficient production by allowing higher CRP without penalizing increased RF in heavier cattle. The research highlights the 450 kg CWT group as a crucial economic threshold within the Korean beef market. These

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findings may guide decision-making in beef cattle production and feeding strategies under the revised grading system. The study acknowledges limitations, such as the lack of detailed feed information and the influence of various other factors, suggesting that future research should incorporate a more comprehensive analysis that includes these additional variables for a more nuanced understanding of the economic impacts within the beef grading system. In summary, these findings indicate a significant shift in the economic implications of RF on CRP when moving from the original to the revised grading system, with the latter potentially offering a more balanced and economically beneficial framework for producers of Hanwoo cattle.

CONCLUSION

This study demonstrates that the impact of rib fat thickness (RF) on carcass price (CRP) varies significantly across carcass weight (CWT) groups. In the original grading system, RF consistently exhibited negative coefficients for CRP, regardless of CWT groupings. Contrastingly, in the revised grading system, RF showed both negative and positive coefficients for CRP. A critical finding from this study is the identification of the 450 kg CWT group as the point where the RF's effect on CRP shifts from negative to positive in the revised system. Additionally, our findings could serve as a reference for determining the economic valuation of RF in relation to CRP for different CWT groups under the revised grading system. These insights could be instrumental in informing decision-making processes related to precision feeding systems.

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Conflict of interest

The authors declare no conflict of interest.

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