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ABSTRACT

This study aims to evaluate the effects of quality grade and different muscle types on the physicochemical and sensory properties of Hanwoo beef. This study used the 1++ and Grade 1 quality grades of Hanwoo beef biceps femoris (BF), psoas major (PM) and longissimus dorsi (LD) as the samples, and compared and analyzed the pH value, CIE L*, CIE a*, CIE b*, Warner–Bratzler shear force (WBSF), moisture, cooking loss and sensory evaluation of the six groups of samples. The results showed that the different muscle types of Hanwoo beef aged about 30 months had different quality characteristics after 11-21 days of carcass maturation. Among them, the physicochemical properties and sensory scores of PM of 1++ and 1 quality grades were the highest, and the pH values of the three groups of 1++ muscle samples were relatively small. The BF sample had a significantly higher WBSF, but also lower tenderness and overall acceptability scores. In summary, under the same quality grade, there are differences in the physicochemical properties and sensory quality of Korean beef from different carcass parts; different quality grades of the same muscle part also exhibit certain quality differences. The results of this study provide a reference for further understanding the quality characteristics of Korean beef from different quality grades and different carcass parts, and for its quality evaluation and rational utilization.

Key words: Hanwoo beef, Sensory evaluation, Quality grade, Muscle types

Introduction

The marbling score of beef has a strong correlation with quality grade (Park et al., 2002). The meat quality of Hanwoo is determined by the color of the lean meat, the color of the fat, the firmness of the loin, and the maturity of the fat. The Korean beef carcass quality grades (1++, 1+, 1, 2, and 3) are primarily determined by the fat distribution score of the longissimus dorsi muscle at the interface between the 13th thoracic vertebra and the 1st lumbar vertebra (Kim and Lee, 2003). Hanwoo carcasses are generally divided into several major parts, each possessing different meat quality characteristics, and these differences directly affect the final quality grade (e.g., grades A, B, and C). The lengths of tenderness characteristics, such as collagen protein content and sarcomere segments, extracted from 10 different muscles of varying quality levels—including the tensor thoracic (LT), tensor lumborum (LL), psoas major (PM), semispinalis (SS), and semimembranosus (SM)—varied significantly (Lee et al., 2017).

The quality of the dorsal muscle (LD) is considered one of the high-quality cuts of Hanwoo, and marbling and fat distribution are crucial for evaluating meat quality (Moon et al., 2006). Grade 1++ LD has an IMF content of 21.5%, whereas Grade 2 LD has an IMF content of only 6.6% (Cho et al., 2010). Compared to low-fat muscle, the IMF content of LD has a greater influence on the IMF content of high-fat muscle (Hwang and Joo, 2016). Hanwoo tenderloin is a beef cut characterized by exceptional tenderness, low fat content, and rich flavor; It is highly praised for its excellent eating quality and is widely regarded as a premium beef product from South Korea. Generally, commercially available Hanwoo undergoes a certain degree of aging, which involves storing the meat at temperatures above freezing (-1 to 1°C) to tenderize it and improve meat quality (Kim et al., 2019). Maturity and intramuscular fat have a certain effect on the quality of Hanwoo tenderloin (Kang et al., 2010). However, lower quality grade groups under the Korean grading system can have a negative effect on the sensory characteristics of Hanwoo tenderloin, and this varies significantly depending on the quality grade group (Yim et al., 2015).

Sensory characteristics, including tenderness, flavor, and juiciness, are important factors determining the palatability of beef (Savell et al., 1987). Acceptable tenderness levels were determined based on chi-square analysis of Warner-Bratzler shear force (WBSF) values, tenderness grades, and consumer judgments regarding tenderness and overall acceptability (Huffman et al., 1996). Flavor is considered a powerful factor in determining overall consumer preference (Kerth and Miller, 2015). Flavor precursors in cooked meat are primarily sugars, peptides, amino acids, inorganic salts, and other non-volatile components found in fresh meat, such as organic acids (Macleod, 1994). Hanwoo has higher levels of total free amino acids and metabolites associated with umami and sweetness, as well as fat-derived volatile compounds (aldehydes, alcohols, ketones) associated with fat flavor (Hoa et al., 2024). Values for tenderness, juiciness, and overall palatability of the tenderloin tended to be highest in the 1++ quality grade, while all sensory characteristics of the sirloin were higher than those of the rump ($p<0.05$) (Piao et al., 2015). In this study, the meat quality characteristics of Grade 1++ and Grade 1 Hanwoo biceps femoris (BF), psoas major (PM) and longissimus dorsi (LD) sold domestically were primarily compared and analyzed. These three types of muscle represent different anatomical locations and physiological functions, and have different meat characteristics. This helps to further understand the effects of carcass quality grade and muscle type on the physicochemical properties and sensory quality of Korean beef.

Materials and methods

Sample preparation

Grade 1++ and Grade 1 Hanwoo BF, PM and LD were randomly purchased from supermarkets in the Jeonju area, three independent samples were obtained for each treatment group (n=3), each weighing nearly 1 kg, were collected. Some samples were placed in baking pans at 180–200°C for sensory evaluation, while the remaining samples were left to test other indicators. Sample information is shown in Table 1.

pH

pH was measured by directly inserting the probe into the meat using a pH meter (Model HI99163, HANNA, Korea) equipped with a glass probe and a temperature sensor. Before measurement, the device was calibrated with pH 4 and 7 standard solutions, and the average value was used after four measurements.

Meat color

After cutting the sample along the direction of the muscle fibers, the cut surface was exposed to oxygen in a cool, dark place for 30 minutes to develop color, and then the lightness (L*), redness (a*), and yellowness (b*) were measured using a colorimeter (CM-2500d, Konica Minolta, Japan). The measurements were repeated three times, and the average value was used. D65 was used as the light source for the measurements.

Moisture content

Moisture content was measured using an HR73 Halogen Moisture Analyzer (Mettler-Toledo GmbH, Switzerland). Approximately 2.5g of the sample was spread evenly after being finely chopped. The drying temperature was 105°C, and the moisture content was calculated as a percentage based on the sample weight after the moisture in the sample had dried. Before moisture content analysis, the instrument was calibrated using double-distilled water, and the data was the average of three measurements.

Cooking loss and Warner–Bratzler shear force (WBSF)

After recording the weight of the sample before heating, a thermometer (Thermo Recorder, TR-52, T&D Corporation, Japan) was inserted into the center of the sample, and the sample was heated in a preheated 70°C constant temperature water bath (DS-23SN, Dasol Scientific Co., LTD., Korea) until the center temperature reached 70°C. Once the internal temperature of the sample reached 70°C, it was immediately removed and cooled in running water (approx. 18°C) for 30 minutes. After cooling, the moisture was removed from the sample using paper, and the weight after heating was measured. The loss on heating was calculated using the following formula.

Cooking loss (%) = (Weight before heating - Weight after heating) / Weight before heating × 100

After cooking and weighing, the sample was placed in a 4°C refrigerator to cool for 24 hours before being used to measure the WBSF value. 7 to 8 analytical samples were prepared using 1.27 cm thick cores, and measurements were taken using an Instron (Model 4465, Instron Corp., USA). For shear force measurement, a V-shaped blade was used to cut the sample perpendicular to the direction of the muscle fibers; the load cell was 50 kg, and the cross-head speed was 400 mm/min. The average value was used after measuring the shear force 6 times per sample.

Sensory evaluation

Sensory evaluations were performed according to a previously established protocol in our laboratory (Dashdorj et al., 2012). The team consisted of 10 trained personnel. Each sample was cut to a size of 4 cm (length) x 3 cm (height) x 0.5 cm (thickness) for testing. Each sample was evaluated three times by the same panelists. Judges evaluated tenderness, juiciness, flavor, overall acceptability, and the total score. Each panelist evaluated the cooked beef samples in a random order, and after the test, each panelist was required to provide a value from 1 to 100 (i.e., unacceptable to highly acceptable). Each reviewer was asked to refresh their mouth with distilled water (DW) between tasting samples.

Statistical analysis

The results for each treatment group are expressed as mean, and the SEM in the table is the standard error of the mean calculated by the model. A two-way analysis of variance (ANOVA) based on the general linear model was performed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$. Figures were generated using Origin 2024 (Origin Labs, Massachusetts) and R.

Results and Discussion

Analysis of differences in color by different beef cut

Color is an important factor influencing consumers' meat purchasing decisions. Discolored meat reduces consumer purchasing desire and can even lower the value of the meat, potentially leading to economic losses (Lee and Shin, 2019). Table 2 shows the results of color tests on two quality grades of three Hanwoo carcass cuts (LD, BF, and PM). Overall, the CIE L* value of LD is slightly higher than that of BF and PM, indicating higher brightness of LD. The higher L value observed in LD may be related to intrinsic differences in muscle characteristics. Previous studies have suggested that glycolytic muscles generally exhibit lighter color than oxidative muscles because of differences in muscle fiber composition, oxidative metabolism, and myoglobin content. Therefore, the relatively higher L value of LD compared with BF and PM is likely associated with these muscle-specific characteristics (Lawrie and Ledward, 2014; Mancini and Hunt, 2005). The CIE a* crossover point of PM is slightly higher than that of LD and BF, while there is no significant difference in CIE b* among PM, BF, and LD. Color stability may vary depending on the muscle type due to differences in oxygen consumption rates and myoglobin reductase activity (Kim et al., 2017).

Analysis of differences in pH by different beef cut

The pH value of beef is one of the most important quality factors (Lee and Yun, 2015). As shown in Table 2, the pH value 24 hours after slaughter for Hanwoo of different quality grades ranges from 5.48 to 5.56 (Cho et al., 2010). Once muscle glycolysis is complete, there is almost no difference in pH values. The pH value of beef can increase significantly as the aging time lengthens (Kim et al., 2022). While there is no significant difference in pH among Hanwoo BF, PM, and LD of the same quality grade, the pH of Grade 1 LD and BF is higher than that of the corresponding Grade 1. Excluding Grade 1++ beef and Grade 1 BF, all values are within a reasonable slightly acidic range. High-quality beef typically has a higher intramuscular fat content, and its muscle composition and tissue structure differ somewhat from ordinary quality beef; these factors may be related to the differences in final pH value.

Analysis of differences in moisture content by different beef cut

Meat juiciness is the initial sensation provided by moisture released from the surface of the meat during chewing and also reflects the degree to which saliva is induced (Muir et al., 1998). Meat juiciness depends primarily on muscle moisture content, which can be influenced by diet, genetics, and carcass condition (Mwangi et al., 2019). As shown in Table 2, for the muscles of three different carcass parts, the moisture content of high-quality grade samples is indeed lower for LD. Generally, the ratio of intramuscular fat is inversely proportional to moisture content (Kim and Lee, 2003), which also confirms the effect of intramuscular fat content in the dorsal muscle on the grade of Hanwoo.

Analysis of differences in cooking loss by different beef cut

As shown in Table 2, LD has the lowest cooking loss, while PM has the highest. Furthermore, the cooking loss rate of LD Grade 1++ was lower than that of LD Grade 1, which appears to be due to the lower cooking loss rate of beef with a high marbled pattern (Ozawa et al., 2000).

The cooking loss rates of Grade 1++ BF and PM samples were higher than those of their corresponding Grade 1 samples. While these samples also had higher water content, water content alone cannot fully explain the higher cooking loss rates. Cooking loss rates are influenced by a variety of factors, including water-holding capacity, pH, protein denaturation, and muscle structure. Therefore, the higher cooking loss rates observed in Grade 1++ BF and PM samples are likely related to differences in water-holding capacity and muscle properties, rather than just water content. Studies have shown that high pH can enhance the water-holding capacity of beef by changing the distance between proteins and their isoelectric points, thus reducing cooking loss to some extent (Lawrie and Ledward, 2014). Differences in muscle fiber composition and connective tissue content in different parts of the body, as well as variations in the degree of muscle fiber contraction during heating, may also lead to differences in cooking loss (Boakye and Mittal, 1993).

Analysis of differences in WBSF among different beef cuts

Post-aging is a common industry practice to improve the tenderness and palatability of beef (Nair et al., 2019). A decrease in pH affects muscle proteins in the meat (e.g., actin and myosin). These proteins denature, losing their original structure and elasticity, which affects the tenderness of the meat. WBSF is one method for measuring meat tenderness (Choe et al., 2016). As shown in Figure 1, The shear force of LD 1++ is significantly lower than that of Grade 1. The intramuscular fat in beef gradually breaks down during the aging process, releasing certain chemicals that promote meat tenderization. High-quality beef generally contains more internal fat, which helps maintain tenderness during aging. BF has the highest shear force, while PM has the lowest. Tenderness changes differently in various parts of the muscle during post-aging (Nair et al., 2019).

Differences in sensory evaluation of different cuts of Hanwoo beef

Animal age, carcass processing before and after slaughter, the decrease in pH values after slaughter, and marbling can all affect the tenderness of beef (Špehar et al., 2008). Generally, male calves and female cows with thicker subcutaneous fat and greater marbling receive higher tenderness scores (Jeremiah, 1996). As shown in Table 3, The tenderness scores of the 1++ and Grade 1 PM samples were 75.00 and 80.83, respectively, which were significantly higher than the tenderness scores of the two groups of BF samples (33.33 and 20.00) ($p < 0.01$). Tenderness scores for LD and BF 1++ were significantly higher than those for Grade 1 ($p < 0.01$), but the difference between PM 1++ and Grade 1 was not significant. Among the six samples of LD, BF, and PM, the difference in flavor scores was identical to the difference in tenderness scores, confirming to some extent that the tenderloin muscle is more flavorful (Carmack et al., 1995). These differences may be caused by differences in intramuscular fat content. The influence of marbling on the taste of beef is also evident. The higher the intramuscular fat content and the greater the variety of fatty acids, the greater the influence on taste. As a result, PM exhibited the highest juiciness grade, and the juiciness of PM, LD, and BF 1++ grades was all higher than that of Grade 1; furthermore, muscle fibers and connective tissue levels were all high across different carcass parts. Both muscle content and water supply influence the juiciness of beef. In addition to these factors, beef of the 1++ quality grade has higher marbling and tenderness scores, which is one of the reasons why beef of higher quality grades has higher juiciness scores. As shown in Figure 2, participants' preference for the samples has a positive correlation with flavor, tenderness ($p < 0.01$), and juiciness, and it can be seen that water content has a significant correlation with flavor, tenderness, and juiciness. WBSF had a significant negative correlation with tenderness, flavor, and likeability ($p < 0.01$, $p < 0.05$), and also had a negative correlation with juiciness. This relationship can also be confirmed by the fact that the likeability rating, overall likeability score, and acceptance ratio for each characteristic generally increase as fat content increases (Corbin et al., 2015).

This study has certain limitations. Because of the differences in aging times among different sample groups, and because aging time has been proven to affect beef pH, water retention, tenderness, shear strength, and sensory quality, some of the differences observed in this study may not only originate from muscle location or quality grade but may also be influenced by differences in aging time. Therefore, caution should be exercised when interpreting the results of this study. Future research should strive to standardize the aging times of all samples or include aging time as a covariate in statistical analysis to further clarify the independent effects of muscle location and quality grade on beef quality.

Conclusion

Among the three different parts of the carcass, LD had a lighter color, the pH values of the three groups of 1++ grade samples were slightly lower than those of the grade 1 samples, PM 1++ had the lowest shear force, and BF 1++ had the highest. PM 1++ had the highest juiciness grade, while PM 1 had the highest flavor and tenderness grades. Accordingly, participants rated PM the highest in terms of preference, and in particular, PM 1++ received the highest scores for its meat characteristics and texture, which exhibited the most favorable sensory characteristics among the three muscle types. Overall, Grade 1++ generally exhibited more favorable meat quality characteristics than Grade 1; however, the observed differences depended on the specific quality trait and muscle type.

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Table 1. Carcass quality, slaughter age, and sample aging time

Item	LD		BF		PM		SEM	P-Value
	1++	1	1++	1	1++	1		
Carcass weight/kg	470.67ab	390.33b	465.00ab	435.33ab	484.33a	427.67ab	11.87	0.206
Age/month	29.67b	30.67ab	33.33a	32.00ab	30.67ab	31.00ab	0.43	0.188
Chiller aging/day	14.00bc	20.00ab	15.00abc	11.33c	21.00a	20.00ab	1.12	0.026

BF for the cut of biceps femoris muscle in Hanwoo beef, PM for the cut of psoas major muscle in Hanwoo beef, LD for the cut of longissimus dorsi muscle in Hanwoo beef.

Table 2. pH value, color, moisture content and cooking loss of Hanwoo beef

Item	LD		BF		PM		SEM	P-Value
	1++	1	1++	1	1++	1		
PH	5.97a	6.07a	5.48c	6.28a	5.57bc	5.88ab	0.12	< 0.01
CIE L*	42.78a	43.68a	40.95a	41.37a	41.05a	40.90a	0.57	0.648
CIE a*	19.74a	18.56a	18.34a	19.14a	21.00a	20.14a	0.37	0.303
CIE b*	10.21ab	9.62ab	8.94b	9.92ab	11.24a	9.82ab	0.28	0.284
Moisture/%	53.41c	60.82b	64.46ab	67.25a	65.32ab	67.03a	1.10	< 0.01
Cooking Loss/%	17.74c	19.06bc	22.05ab	20.47bc	25.05a	24.60a	0.60	< 0.01

When the p-value for the interaction term between quality grade and muscle type is less than 0.05, it indicates a significant interaction between the two factors. BF for the cut of biceps femoris muscle in Hanwoo beef, PM for the cut of psoas major muscle in Hanwoo beef, LD for the cut of longissimus dorsi muscle in Hanwoo beef.

Table 3. Sensory evaluation of two quality grades by Hanwoo carcass part

Item	LD		BF		PM		SEM	P-Value
	1++	1	1++	1	1++	1		
Flavor	58.33ab	48.33ab	40.83ab	32.50b	55.83ab	63.33a	3.04	0.02
Tenderness	63.33ab	55.00ab	33.33bc	20.00c	75.00a	80.83a	4.94	< 0.01
Juiciness	70.00abc	58.33bc	79.17ab	50.00c	88.33a	75.83ab	3.13	< 0.01
Likes	56.05ab	46.50bc	42.88bc	25.63c	66.67a	66.45a	5.48	< 0.01

When the p-value for the interaction term between quality grade and muscle type is less than 0.05, it indicates a significant interaction between the two factors. BF for the cut of biceps femoris muscle in Hanwoo beef, PM for the cut of psoas major muscle in Hanwoo beef, LD for the cut of longissimus dorsi muscle in Hanwoo beef.

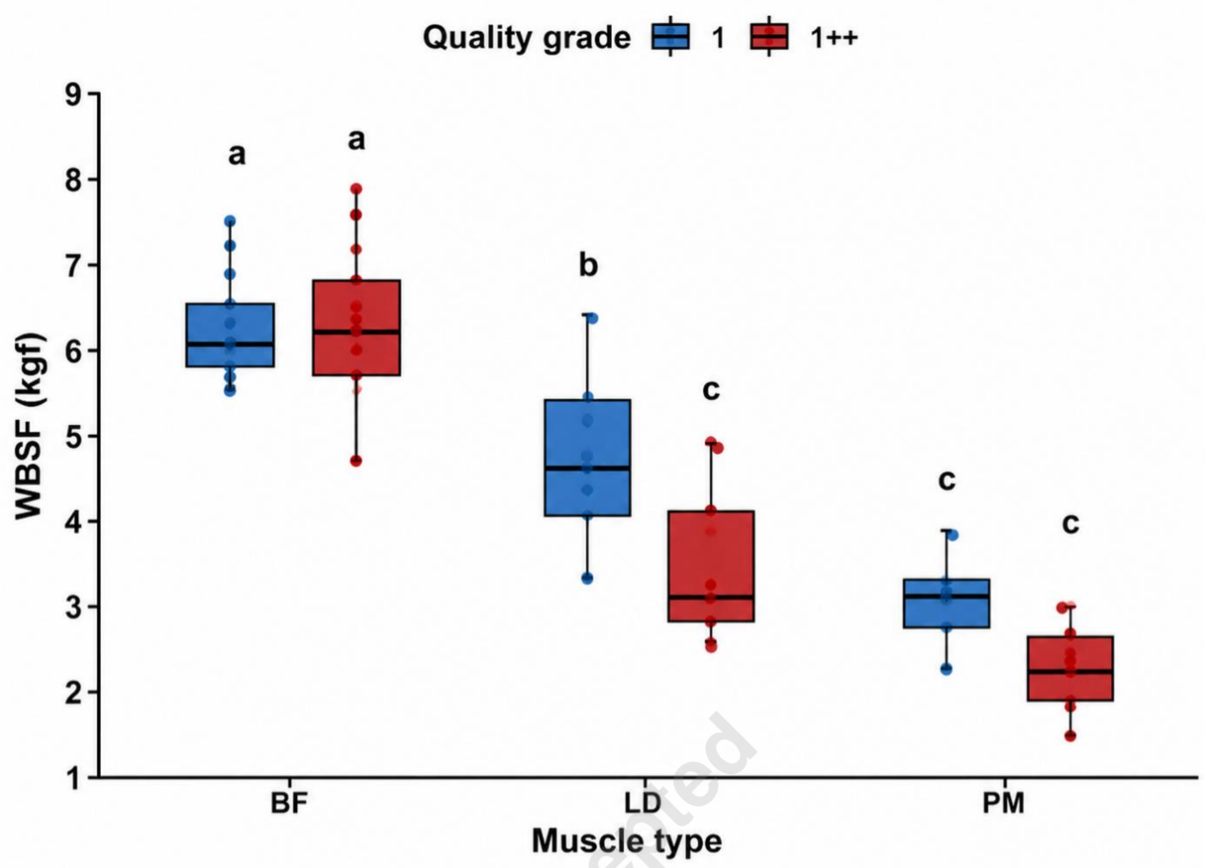

Figure 1. Warner－Bratzler shear force for different cuts of Hanwoo beef. BF for the cut of biceps femoris muscle in Hanwoo beef, PM for the cut of psoas major muscle in Hanwoo beef, LD for the cut of longissimus dorsi muscle in Hanwoo beef.

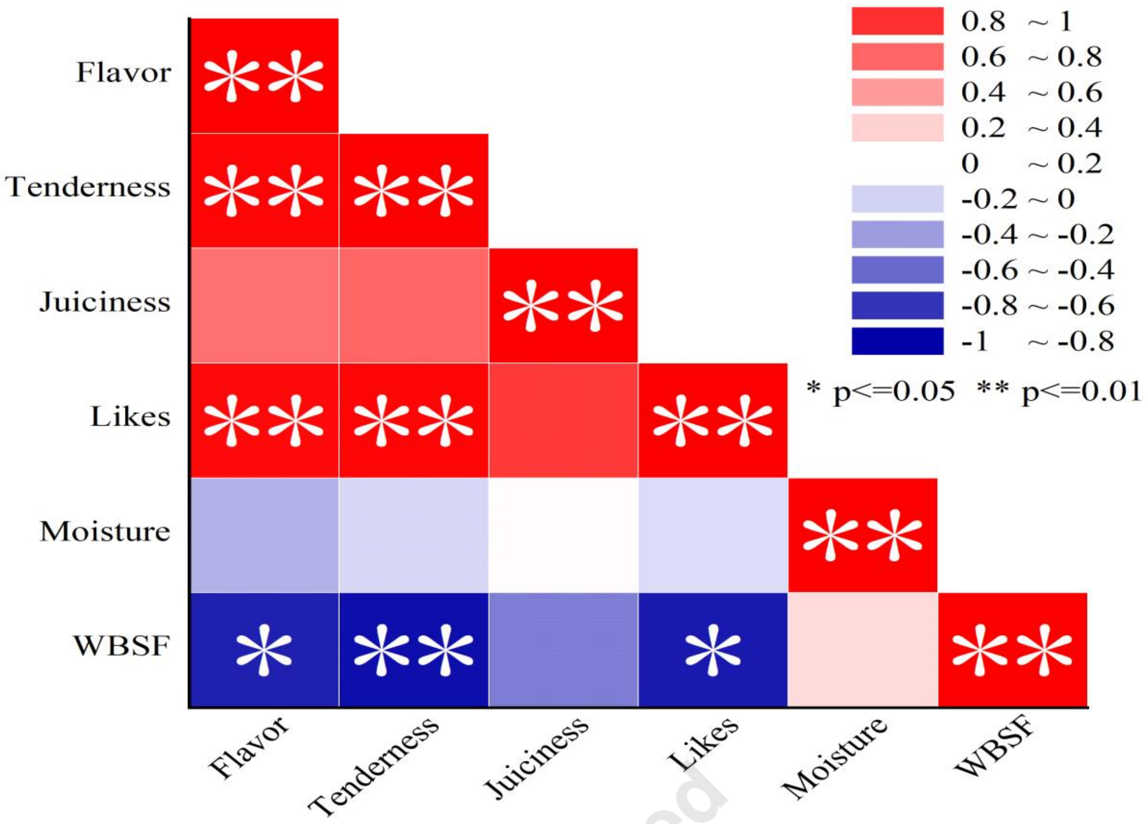

Figure 2. Pearson correlation coefficient between sensory scores and moisture content of two quality grades by Hanwoo carcass part