Market weight, slaughter age, and yield grade to determine economic carcass traits and primal cuts yield of Hanwoo beef

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Abstract

This study was conducted to evaluate the relationship among market weight, slaughter age, yield grade, and primal cut yield in Hanwoo. A total of 403 Hanwoo (Korean native cattle) was assessed for carcass traits such as carcass cold weight, backfat thickness, ribeye area, dressing percentage, yield index, and marbling score. The production yield of the individual major primal cuts of Hanwoo beef was also measured. Carcass cold weight, ribeye area, and backfat thickness, which affect meat quality increased with increased market weight ($p<0.05$). The production yield of the ten major primal cuts also increased with increased market weight ($p<0.05$). In terms of slaughter age, carcass cold weight, ribeye area, and backfat thickness all increased from 25 months to 28-29 months, and the production yield of all prime cuts also increased with increasing slaughter age. According to the meat yield grade, carcass cold weight and backfat thickness increased from grade A to grade C, although the ribeye area was not affected. The combined findings of the study suggest that slaughtering Hanwoo at the weight of 651-700 kg and 701-750 and age of 28.23 and 29.83 months could be desirable to achieve the best quality and quantity grade of Hanwoo beef. However, the positive correlation of carcass cold weight and backfat thickness, and the negative correlation of the yield index according to primal cuts yield indicated that it is necessary to couple the slaughtering management of cattle with improved genetic and breeding method of Hanwoo to increase the production yield of the major prime cuts of Hanwoo beef.

Keywords:

Hanwoo, carcass traits, market weight, slaughter age, yield grade, correlation

Introduction

The Korean beef industry is one of the many developed countries that has been long showing trends into marketing individual muscle cuts for consumption (1,2). In South Korea, Hanwoo beef is divided into 10 primal cuts and 39 minor beef cuts according to guidelines of labeling and division of beef and pork meat in Korea (3). A study on the chemical composition and meat quality traits of the 10 primal cuts showed that tenderloin, loin, sirloin, and ribs had the highest overall acceptability (4), and (5)reported that carcass length and the 7th to 8th thoracic vertebrae girth showed to be the most important traits affecting primal cut yields. These recent studies have shown that meat quality and carcass yield traits differ according to the primal cuts. Under the Korean meat market, meat quality and carcass yield are the main drivers that influence marketing price in which the latter greatly affects the profits in beef meat.

The Hanwoo feeding program is heavily reliant on a high-energy feed ration from 6 to 29 months of age, and it has been reported that a 29-month old endpoint is the suitable economic feeding period for Hanwoo (6). However, due to demand for increased marbling scores, livestock farmers have increased the slaughtering age of Hanwoo from 30.2 months in 2009 to 32.5 months in 2014 (7). Marbling score and carcass weight steadily increased with the increasing age of slaughter: 26, 28, and 30 months (8). In some instances such as when meat market prices are low, farmers extend the feeding past normally the optimum market weights of the cattle. The market weight of Hanwoo has increased from 425 kg in the early 1980s (9) to 694 kg in 2011 (10). The average feeding cost of Hanwoo has also increased from 2,170,000 won/head in 2010 to 2,982,000 won/head in 2016 (11). The extension of the feeding period along with the inflation in feed prices poses an economic challenge to livestock farmers and consumers alike.

In this regard, it is indispensable to recognize the influence of market weight and slaughter age of Hanwoo to prime cuts yields of Hanwoo beef and to understand the relative importance of the relationship between carcass traits and yield grade. Therefore, the objective of this study was to mainly determine the influence of market weight, slaughter age, and yield grade on the yield of ten primal cuts and economic carcass traits. In addition, the correlation of the carcass traits with the yield of the primal cuts was analyzed to better understand the contributing factors that affect the economic carcass characteristics of Hanwoo.

Materials and Methods

Animal management

A total of 403 Hanwoo steers (Korean native cattle) at age of 24 to 35 months was slaughtered at three abattoir locations: Nonghyup Eumseong Livestock Products Market, Nonghyup Bucheon Livestock Products Market, and Hyupshin Foods from April to July 2021. The commercial slaughter of the Hanwoo steers followed the guidelines of the Korean Animal Protection Law (Article 6), and the Livestock Sanitation Control Act Law (Annex I).

Carcass characteristics evaluation and prime cuts yield measurement

Live weight of the Hanwoo cattle was measured for each head before slaughter after being shipped from the farm to each abattoir. After 24 h post-mortem in a cold room (1℃), carcass cold weight was measured and dressing percentage was calculated, and the left side of the carcass was ribbed between the thoracic vertebra and the first lumbar vertebra to measure the backfat thickness, ribeye area, and the quality traits. Backfat thickness was measured over the medial third part of the ribeye area. The area of the ribeye was determined at the surface of the cut using a standard grid. Marbling was scored in the ribeye area from 1 as rare to 9 as abundant according to the standard (12,13). Yield grade was determined by the carcass cold weight, adjusted backfat thickness, and the ribeye area.

The yield index was calculated by the following equation:

$$Yield\ index = \frac{(11.06398-[1.25149\times Backfat\ thickness\ (mm)]+[0.28293\times Ribeye\ area\ (cm2)]+[0.54768\times Carcass\ cold\ weight\ (kg)])}{(\text{Carcass cold weight (kg)}\times 100)}$$

After measuring the carcass yield traits and grading the yield, the carcasses were dissected into 10 major primal cuts according to guidelines of labeling and division of beef and pork meat in Korea (3). The weight was measured after sampling the 10 primal cuts (tenderloin, sirloin, striploin, chuck, shoulder, bottom round, top round, brisket, shank, and rib) from which all visible fat and bone were separated and weighed.

Statistical analysis

Market weight, slaughter age, and yield grade as functions of each carcass traits (carcass cold weight, ribeye area, backfat thickness, yield index, dressing percentage, marbling score, meat yield, fat yield, and bone yield) were tested by analysis of variance using a general linear model (GLM) performed using SAS (14). Significance levels of the least square mean for each trait were separated by probability at a 5% level. Correlation analysis of the slaughter age, market weight, and of each carcass weight to the primal cut of the Hanwoo was estimated through Pearson’s correlation. Multi regression analysis was performed to determine how much the economic carcass traits affect the ten primal cut yields, and semi-partial analysis was used to indicate the contribution.

Results and Discussion

Carcass yield traits and primal cut yield according to market weight

It is important to make a careful decision on the market weight of the Hanwoo or any breed of beef cattle due to its confounding effect on beef quality, yield grade, and economic aspects. Changes in the economic carcass characteristics according to the market weight of Hanwoo beef were shown in Table 1. Results showed that the carcass cold weight (CCW), ribeye area (REA), and backfat thickness (BFT) increased as the market weight of the Hanwoo increased (p<0.05). Consequently, the meat yield index (MYI) tended to decrease as the market weight increased (p<0.05). The findings in the MYI of the present study were similarly observed in a previous study which reported that there was a significant decrease in the yield index of the Hanwoo as the market weight increased (15,16). The tendency of the market weight to reduce MYI could be due to the increased backfat thickness in this study. The increase in backfat thickness could directly increase the market weight of Hanwoo but could also cause an indirect decrease in the MYI of the beef cattle. As evidenced, the lowest market weight (650 kg) showed the lowest BFT (9.83) and the highest MYI (62.53). The dressing percentage observed in this study ranged from 58.65 to 59.40. Although the observed dressing percentage in this study was lower than the optimized 60.64 dressing percentage reported (17), there were no significant differences observed among the different market weights of the Hanwoo. In terms of marbling, the marbling score (MS) of Hanwoo beef increased significantly with increasing market weight. The highest MS of 3.96 was observed in Hawoo with the market weight of 851kg< and the lowest MS of 3.35 was observed in Hanwoo with the market weight of 650kg>. In the recent review of (18), although the highest market weight reported was 591kg, it was reported that the MS generally increased with market weight in several breeds of cattle. The overall yield in terms of the whole prime cuts, fat weight, and bone weight was observed to significantly increase with market weight (p<0.05) consistent with the previous study of (19). More specifically, the lowest primal cuts yield of 247.65 kg was observed at the lowest market weight (650≥ kg) and the highest yield of 335.32 kg was observed at the highest market weight (851≤ kg). Fat weight yield ranged from 73.05 kg to 132.49 kg, whereas bone yield ranged from 37.58 kg to 49.93 kg.

The changes in the yield of the individual Hanwoo prime cuts according to market weight were presented (Table 2). The average primal cuts yield was 5.40 to 6.84 kg for tenderloin, 29.81 to 39.99 kg for sirloin, 7.45 to 10.06 kg to strip loin, 13.18 to 18.64 kg for chuck, 21.56 to 28.29 kg for shoulder, 20.19 to 26.54 kg for the bottom round, 30.96 to 41.53 kg for top round, 39.23 to 52.46 kg for the brisket, 18.90 to 23.29 kg for the shank, and 58.82 to 85.06 kg for ribs. The yield of the individual primal cut consistently increased as the market weight of Hanwoo increased ($p<0.05$). It was generally expected that the carcass traits and the yield of the individual primal cut increased with market weight. Heavier beef cattle produce heavier carcass weight, consequently resulting in heavier lean meat (prime cuts), fat and bone yield, larger ribeye area, thicker backfat, and accordingly tending to lower the yield index. As higher quality grade is expected from heavier carcasses with thicker backfat and larger ribeye areas, a higher market weight of Hanwoo could result in a better beef quality grade. Some studies reported that carcasses with larger ribeye areas resulted in a lower USDA quality grade (20,21), but a high positive correlation in market weight, marbling, and ribeye area was found according to the Hanwoo grading system (12). Slaughtering at the weight of 651-700 and 701-750 at slaughtering age of 28.23 and 29.83 months, respectively, might be desirable to achieve the best quality and quantity grade of Hanwoo beef.

Carcass yield traits and primal cut yield according to slaughter age

Changes in the economic carcass characteristics according to the slaughter age of Hanwoo beef were shown in Table 3. Results showed that the market weight and CCW increased from 25 months to 30-31 months but there were no changes observed in both the market weight and CCW from 30-31 months to 34 months. Similar to the report of (22), the CCW has stopped progressing after reaching 28 months of age. The REA increased from 25 months to 26-27 months but has stopped increasing upon reaching 28-29 months. The BFT has shown consistent thickness measurement from 25 months to 32-33 and has slightly increased at the age of 34 months or older. In the Japanese black cattle, a similar observation was found where the CCW, REA, and BFT did not show significant differences at slaughter ages of 30 to 34 months of age (23). The overall prime cuts yield and the fat yield increased from 25 months to 28-29 months and have stopped progressing from then to 34 months. Bone yield, on the other hand, increased from 25 months to 26-27 months and kept a steady yield from then to 34 months. The changes in the lean meat production of the individual primal cuts of Hanwoo beef according to slaughter age were shown in Table 4. The average primal cuts yield was 5.49 to 6.34 kg for tenderloin, 31.43 to 36.58 kg for sirloin, 7.86 to 9.08 kg to strip loin, 13.92 to 16.35 kg for chuck, 22.37 to 25.67 kg for shoulder, 20.93 to 24.08 kg for the bottom round, 31.70 to 37.71 kg for top round, 40.88 to 45.94 kg for the brisket, 18.93 to 21.46 kg for the shank, and 67.09 to 72.43 kg for ribs. It can be found in this result that the yield of prime cuts tenderloin, sirloin, shoulder, bottom round, and top round continuously increased from 25 months to 34 months. Strip loin, chuck, brisket, shanks, and ribs increased from 25 months to 26-27 months and kept a steady lean meat yield from then on to 34 months. In terms of marbling quality, the MS recorded in this study according to slaughter age ranged from 3.47 to 4.01 and there were no significant differences observed among the different slaughter ages of the Hanwoo beef. Contrary to studies, the MS generally increased with slaughter age in Korean cattle (18). The MS of Korean steers increased from 6.0 to 7.06 at 26 to 31 months of slaughter age while the MS of the Korean beef cattle regardless of sex increased 4.9 to 5.7 at 26 to 35 months of slaughter age (24). Summing up, the carcass yield traits of Hanwoo beef such as market weight, CCW, REA, BFT, overall and individual prime cut yield, fat weight, and bone weight progressed until at the age of 27 to 28 months. As evidenced by the carcass yield traits and the comparable MS among different slaughter ages, this study suggests that there was no negative impact at slaughtering Hanwoo beef cattle at a young age. Reducing the slaughter age to 28 months which is 4.5 months shorter than the commonly practiced slaughter age of 32.5 months (7,11) showed the best results of carcass yield traits without compromising the quality of marbling of Hanwoo beef. The slaughter age at 28 months would be economically sufficient as the carcass yield traits and the individual prime cut yield was consistently the same across all slaughter age from 28 to 34 months. Studies by (22) and (25) also suggested that at 28 and 29-month old endpoints, respectively, is a suitable slaughter age for Hanwoo. In addition, it was reported that the optimum slaughter age for Korean cattle to give the highest profit was 28 months irrespective of the gender of the animals (26)(18).

Carcass yield traits and primal cut yield according to yield grade

The Korean grading system of meat yield consists of three grades: A, B, C grades depending on the meat yield indexes computed from REA, BFT, and CCW, and with grade A as the highest. Changes in the economic carcass characteristics according to the yield grade of Hanwoo beef were shown in Table 5. The CCW and BFT were found to decrease as the grade increased (p<0.05), while the REA did not show a significant difference with yield grade. The MYI increased with increasing yield grade in which grades A, B, and C have shown yield index of 63.21, 61.44, and 58.99, respectively. The combination of increased CCW and BFT, and decreased yield index was consistent with the findings of the previous studies (27–29). The dressing percentage was highest in grade C at 59.77 (p<0.05) and there was no difference between grades A and B. The primal cuts yield was lowest at 277.74 kg in grade A. The fat yield increased significantly as the grade decreased (p<0.05), while the bone yield did not differ in yield grades. Most importantly, the market weight of grades A, B, and C were 708.27 kg, 757.54 kg, and 800.11 kg, showing an increasing trend with decreasing grades (p<0.05). Slaughter age by yield grade was 28.58 months for grade A, 29.68 months for grade B, and 30.17 months for grade C, in which grade A was found significantly higher than B and C. Similarly, slaughter age of 929.1 days for Grade A, 940.7 days for Grade B, and 961.4 days for Grade C was reported by (22). These results signify that prolonging the slaughter age could lower the yield grade of Hanwoo. It has been reported that the average slaughtering age in the Hanwoo industry has shifted from 30.2 months in 2009 to 32.5 months in 2014, and this extension of feeding period has shown a decrease in the rate of yield grade A from 43% in 2003 to 26.1% in 2015 (7). Hence, establishing the slaughter age to 28-29 months could avoid lowering the yield grade of Hanwoo. The changes in the lean meat production of the individual primal cuts of Hanwoo beef according to yield grade have been shown in Table 5. Among the ten primal cuts of Hanwoo beef, tenderloin, striploin, chuck, shoulder, and bottom round did not differ according to yield grade. Yield grades B and C have shown significantly higher production of prime cuts sirloin, top round, and brisket. Yield grade C, on the other hand, has shown higher production of shank and ribs than the other two yield grades. It can be implied that increased production of shank and ribs could lower the yield grade of Hanwoo. In addition, increased production of sirloin, top round, and brisket could give Hanwoo a yield grade of B and C.

Correlation of carcass yield traits with primal cuts yield

The distribution of muscle, fat, and bone change as the cattle mature over time. Factors affecting the fat deposition and distribution of tissue such as gender, breed, and energy partitioning have been identified and established years ago (30,31) but few have studied the tissue distribution to different parts of the cattle. The simple correlation between the carcass traits and the primal cuts yield was shown in Table 7. The correlation coefficients between the slaughter age and the ten primal cuts were 0.14 to 0.23 indicating a low significant positive correlation (p<0.001). Market weight correlation among the ten primal cuts was observed highest in the ribs at 0.84 followed by sirloin and top round at 0.77, shoulder at 0.75, strip loin and bottom round at 0.72, brisket at 0.70, tenderloin and chuck at 0.67, and the lowest in shank at 0.55 (p<0.001). The correlation of CCW among the ten primal cuts was observed highest in the ribs and sirloin (0.89 and 0.81) followed by top round, shoulder, and strip loin (0.78, 0.77, 0.75) which is consistent with previous reports (5,24). The BFT did not show a significant correlation with tenderloin, chuck, and shoulder, and showed a low significant positive correlation to the other seven primal cuts (0.11 to 0.42). The highest positive correlation of the REA was observed in striploin at 0.71 and sirloin at 0.63 (p<0.001). The dressing percentage showed a significant positive correlation ranging from 0.19 to 0.44 with all the ten primal cuts of Hanwoo beef (p<0.001), while the yield index showed a significant negative correlation with all the ten primal cuts except tenderloin, chuck, and bottom round. Among the factors determining the Hanwoo meat quality, the marbling score showed a significant positive correlation with the sirloin at 0.21

(p<0.001), strip loin at 0.15 (p<0.001), and ribs at 0.17 (p<0.01). Among the ten primal cuts, tenderloin, sirloin, strip loin, and ribs have shown the highest overall acceptability due to their increased fat content and tenderness (4). Generally, these prime cuts cost the most among other prime cuts. Rib prime cut is notable for its high marbling, tenderness, and distinctive flavor while the loin parts (tenderloin, sirloin, striploin) located directly behind the ribs are not heavily used therefore, has increased tenderness. By increasing the market weight and age of the Hanwoo, CCW and REA of tenderloin were significantly increased. By increasing the market weight and age of the Hanwoo, CCW, REA, and BFT of sirloin and striploin were increased. However, the increased BFT for the two prime cuts reduced the MYI of the respective cuts. In terms of marbling, market weight and age were positively correlated with MS in sirloin and striploin. The MS of the rib prime cut was also positively related with market weight and age. The rib prime cut was also the most positively correlated with slaughter age, market weight, CCW, REA, and BFT. The highly positive correlation of BFT with rib prime cut consequently showed the highest negative correlation of MYI. Altogether, increasing the market weight and age in sirloin, strip loin, and rib prime cuts could increase CCW, REA, BFT, and dressing percentage but could decrease MYI. Hence, it is important to determine the optimum market weight and slaughter age at which the best meat yield is produced which in this study is suggesting at 28 months. Nevertheless, the MS of the sirloin, strip loin, and ribs increased with increasing slaughter age and time. Slaughter age and market weight showed a positive correlation to these four cuts indicating that increasing production yield of tenderloin, sirloin, strip loin, and the ribs could be managed by prolonged growth of Hanwoo. Increasing the beef quality of sirloin, strip loin, and ribs as affected by marbling can be managed by increasing slaughter age and market weight as shown in the correlation analysis result.

Multiple regression analysis

The regression analysis and the contribution of carcass traits according to primal cuts yield were shown in Table 8. The regression coefficients by carcass traits that affect the production of prime cuts of beef showed that all ten prime cuts showed positive regression coefficients with CCW and negative regression coefficients with BFT. The REA also showed a positive regression coefficient in all prime cuts except the ribs. These findings imply that CCW and REA positively affect the yield of the prime cuts of Hanwoo beef while the BFT negatively affects the primal cut yield of the Hanwoo beef. In terms of a contribution analysis, the highest contribution predicting the production yield of all the prime cuts of Hanwoo beef was observed in CCW among the carcass traits. The contribution analysis implies that CCW contributes as a driving factor in measuring the yield of the prime cuts.

The CCW could highly affect the meat yield measurement of the ten prime cuts. Taken together, CCW, BFT, and REA were relevant factors in the production of the ten primal cuts of the Hanwoo.

Conclusion

Carcass cold weight, ribeye area, and backfat thickness all increased as the market weight increased, and the meat yield index increased as the market weight decreased. The production yield of all prime cuts increased with increasing market weight. In terms of slaughter age, carcass cold weight, ribeye area, and backfat thickness all increased from 25 months to 28 months, and the production yield of all prime cuts also increased with increasing slaughter age. According to the meat yield grade, carcass cold weight and backfat thickness increased from grade A to grade C, although the ribeye area was not affected. The combined findings of the study suggest that slaughtering Hanwoo at the weight of 651-700 kg and 701-750 and age of 28.23 and 29.83 months might be desirable to achieve the best quality and quantity grade of Hanwoo beef. However, the positive correlation of carcass cold weight and backfat thickness, and the negative correlation of the yield index according to primal cuts yield indicated that it is necessary to couple the slaughtering management of cattle with improved genetic and breeding method of Hanwoo to increase the production yield of the major prime cuts of Hanwoo beef.

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Ethics Approval

All experimental procedures complied with the guidelines of the Korean Animal Protection Law (Article 6), and the Livestock Sanitation Control Act Law (Annex I).

Competing Interests

The authors have no potential personal or financial conflict of interest relevant to this article to report.

Availability of data and material

The results and data of this study can be available from the corresponding author upon reasonable request.

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Table 1. Least square means (±SD) of carcass traits according to Hanwoo market weight

Carcass Traits	Market weight, kg					
	650≥ n=23	651-700 n=69	701-750 n=88	751-800 n=113	801-850 n=63	851≤ n=47
Slaughter age, month	28.83±3.01^{cd}	28.23±2.71^{d}	29.83±2.66a^{bc}	29.62±2.33^{bc}	30.24±2.41^{ab}	30.79±2.28^{a}
CCW, kg	367.43±15.78^{f}	397.72±14.49^{e}	425.64±15.90^{d}	458.56±17.25^{c}	490.95±15.50^{b}	529.36±25.86^{a}
Ribeye area, cm^2	78.78±5.68^{d}	84.43±7.57^{c}	87.14±7.58^{c}	91.93±8.21^{b}	93.4±7.11^{ab}	95.77±8.03^{a}
Backfat thickness, mm	9.83±4.90^{d}	11.83±3.78^{c}	12.82±4.65^{bc}	14.19±4.80^{b}	16.70±5.99^{a}	17.19±5.83^{a}
Yield index[1)]	62.53±1.69^{a}	61.85±1.31^{b}	61.42±1.49^{bc}	61.01±1.46^{c}	60.16±1.63^{d}	59.95±1.50^{d}
Dressing percentage, %	58.84±2.06	58.65±1.77	58.66±1.73	59.22±1.82	59.35±1.55	59.40±1.63
Marbling score[2)]	3.35±1.11^{b}	3.80±1.30^{ab}	3.77±1.24^{ab}	4.01±1.24^{a}	4.08±1.08^{a}	3.96±1.18^{a}
Primal cuts yield, kg	247.65±11.15^{f}	260.81±11.73^{e}	277.23±12.72^{d}	295.41±13.41^{c}	311.44±15.08^{b}	335.32±19.10^{a}
Fat yield, kg	73.05±10.54^{f}	88.69±9.78^{e}	96.78±14.64^{d}	108.33±16.21^{c}	123.19±14.84^{b}	132.49±18.27^{a}
Bone yield, kg	37.58±2.42^{d}	38.93±3.28^{d}	41.62±3.35^{c}	44.28±4.30^{b}	45.45±3.24^{b}	49.93±5.36^{a}

$^{a\text{-}f}$ Means within the same row with different superscript are statistically different ($p < 0.05$); CCW, carcass cold weight

[1)]Yield index : (11.06398 – [1.25149 × Backfat thickness (mm)] + [0.28293 × Ribeye area (cm^2) + [0.54768 × Carcass cold weight (kg)]) ÷ (Carcass cold weight (kg) × 100)

[2)]Marbling Score: 1-trace, 9-very abundant

Table 2. Least square means (±SD) of ten major primal cuts yields according to Hanwoo market weight

Item	Market weight(kg)					
	650≥ n=23	651-700 n=69	701-750 n=88	751-800 n=113	801-850 n=63	851≤ n=47
Tenderloin, kg	5.40 ± 0.35^{e}	5.52 ± 0.37^{e}	5.89 ± 0.51^{d}	6.12 ± 0.47^{c}	6.41 ± 0.50^{b}	6.84 ± 0.55^{a}
Sirloin, kg	29.81 ± 2.29^{f}	31.53 ± 2.57^{e}	33.31 ± 2.40^{d}	35.75 ± 2.48^{c}	37.63 ± 2.59^{b}	39.99 ± 2.93^{a}
Strip loin, kg	7.45 ± 0.58^{f}	7.90 ± 0.68^{e}	8.35 ± 0.75^{d}	8.96 ± 0.82^{c}	9.47 ± 0.81^{b}	10.06 ± 0.84^{a}
Chuck, kg	13.18 ± 1.41^{d}	13.84 ± 1.53^{d}	14.75 ± 1.91^{c}	16.14 ± 1.78^{b}	16.79 ± 1.76^{b}	18.64 ± 2.27^{a}
Shoulder, kg	21.56 ± 1.39^{f}	22.28 ± 1.39^{e}	23.66 ± 1.70^{d}	25.22 ± 1.90^{c}	26.41 ± 1.93^{b}	28.29 ± 2.50^{a}
Bottom round, kg	20.19 ± 1.13^{f}	21.02 ± 1.48^{e}	22.08 ± 1.78^{d}	23.55 ± 1.97^{c}	24.63 ± 1.87^{b}	26.54 ± 2.32^{a}
Top round, kg	30.96 ± 2.09^{f}	32.26 ± 2.08^{e}	34.54 ± 2.57^{d}	36.86 ± 2.95^{c}	38.91 ± 2.55^{b}	41.53 ± 2.91^{a}
Brisket	39.23 ± 3.70^{f}	40.79 ± 3.70^{e}	43.65 ± 3.45^{d}	45.75 ± 3.93^{c}	48.00 ± 4.360^{b}	52.46 ± 4.80^{a}
Shank, kg	18.90 ± 2.05^{d}	19.28 ± 2.02^{d}	20.21 ± 1.71^{c}	20.99 ± 1.92^{c}	21.83 ± 2.32^{b}	23.29 ± 2.68^{a}
Rib, kg	58.82 ± 4.09^{f}	64.17 ± 3.86^{e}	68.51 ± 4.76^{d}	73.69 ± 5.08^{c}	78.99 ± 5.61^{b}	85.06 ± 7.40^{a}

$^{a\text{-}f}$ Means within the same row with different superscripts are statistically different ($p<0.05$)

Table 3. Least square means (±SD) of carcass traits according to slaughter age

Trait	Slaughter age, month					
	25≥ n=15	26~27 n=87	28~29 n=96	30~31 n=106	32~33 n=71	34≤ n=28
Market weight, kg	687.13±54.27^{c}	738.11±65.87^{b}	751.92±70.22^{ab}	777.99±74.82^{a}	781.51±74.50^{a}	779.86±76.06^{a}
CCW, kg	405.40±36.95^{c}	435.46±41.53^{b}	444.55±46.4^{ab}	460.62±47.78^{a}	459.49±49.64^{a}	460.14±51.54^{a}
REA, cm^2	84.67±9.01^{b}	90.43±8.62^{a}	89.39±9.89^{a}	89.40±7.86^{a}	89.75±9.62^{a}	89.75±7.22^{a}
BFT, mm	12.53±4.94^{b}	13.14±4.83^{b}	13.28±4.97^{b}	14.40±5.43^{ab}	14.66±5.29^{ab}	16.43±7.26^{a}
Yield index[1)]	61.59±1.71^{a}	61.47±1.53^{ab}	61.28±1.51^{ab}	60.85±1.68^{abc}	60.80±1.54^{bc}	60.38±2.13^{c}
DP, %	58.96±1.31	58.99±1.66	59.08±1.72	59.20±1.85	58.75±1.86	58.94±1.90
MS[2)]	3.47±0.99	3.94±1.40	3.77±1.19	3.95±1.18	4.01±1.18	3.79±1.07
PCY, kg	262.89±21.32^{c}	283.47±26.20^{b}	288.84±28.11^{ab}	294.66±26.55^{ab}	294.85±28.90^{ab}	298.14±31.49^{a}
Fat yield, kg	94.22±18.72^{c}	99.99±17.75^{bc}	101.99±20.87^{abc}	111.76±23.45^{a}	109.90±21.87^{ab}	106.83±23.84^{ab}
Bone yield, kg	38.96±3.35^{b}	42.13±5.03^{a}	43.39±5.28^{a}	43.76±4.76^{a}	44.13±4.63^{a}	44.30±6.95^{a}

$^{a-c}$ Means within the same row with different superscript are statistically different ($p<0.05$); CCW, carcass cold weight; REA, ribeye area; BFT, backfat thickness; DP, dressing percentage; MS, marbling score; PCY, primal cuts yield

[1)]Yield index : (11.06398 – [1.25149 × Backfat thickness (mm)] + [0.28293 × Ribeye area (cm^2) + [0.54768 × Carcass cold weight (kg)]) ÷ (Carcass cold weight (kg) × 100)

[2)]Marbling Score: 1-trace, 9-very abundant

Table 4. Least square means (±SD) of ten major primal cuts yields according to slaughter age

Item	Slaughter age, month					
	25≥ n=15	26~27 n=87	28~29 n=96	30~31 n=106	32~33 n=71	34≤ n=28
Tenderloin, kg	5.49±0.39[c]	5.98±0.60[b]	6.01±0.63[b]	6.12±0.61[ab]	6.12±0.61[ab]	6.34±0.70[a]
Sirloin, kg	31.43±2.88[c]	34.32±3.60[b]	34.62±3.89[b]	35.35±3.48[ab]	35.63±4.27[ab]	36.58±3.65[a]
Strip loin, kg	7.86±0.62[b]	8.61±0.96[a]	8.76±1.18[a]	8.79±1.00[a]	9.00±1.08[a]	9.08±1.07[a]
Chuck, kg	13.92±1.72[b]	15.22±2.41[a]	15.64±2.22[a]	15.99±2.13[a]	15.84±2.59[a]	16.35±2.92[a]
Shoulder, kg	22.37±1.71[c]	24.09±2.65[b]	24.62±2.71[ab]	25.16±2.35[ab]	25.03±2.68[ab]	25.67±3.35[a]
Bottom round, kg	20.93±1.50[c]	22.67±2.51[b]	23.16±2.58[ab]	23.26±2.43[ab]	23.5±2.63[ab]	24.08±2.91[a]
Top round, kg	31.70±2.98[c]	35.45±3.93[b]	35.81±3.91[b]	36.61±3.78[ab]	36.78±4.12[ab]	37.71±4.14[a]
Brisket	40.88±4.13[b]	43.95±5.12[a]	45.74±5.24[a]	45.83±5.27[a]	45.70±5.44[a]	45.94±6.15[a]
Shank, kg	18.93±1.81[b]	20.72±2.32[a]	20.63±2.41[a]	20.97±2.32[a]	21.05±2.39[a]	21.46±2.94[a]
Rib, kg	67.09±8.48[b]	70.22±7.86[ab]	71.43±8.37[a]	74.29±8.95[a]	73.75±9.41[a]	72.43±9.42[a]

[a-c] Means within the same row with different superscripts are statistically different ($p<0.05$)

Table 5. Least square means (±SD) of carcass traits according to yield grade

Trait	Yield grade		
	A (n=74)	B (n=215)	C (n=114)
Market weight, kg	708.27±60.91^{c}	757.54±66.31^{b}	800.11±74.46^{a}
Age of slaughter, month	28.58±2.41^{b}	29.68±2.56^{a}	30.17±2.69^{a}
Carcass cold weight, kg	414.18±37.79^{c}	445.65±42.48^{b}	478.19±46.86^{a}
Ribeye area, cm^2	89.43±9.69	89.35±8.86	89.92±8.40
Backfat thickness, mm	7.82±2.03^{c}	12.50±2.13^{b}	20.76±3.94^{a}
Yield index[1)]	63.21±0.56^{a}	61.44±0.61^{b}	58.99±1.07^{c}
Dressing percentage, %	58.48±1.76^{b}	58.81±1.61^{b}	59.77±1.82^{a}
Marbling score[2)]	3.53±1.15^{b}	3.88±1.39^{a}	4.14±0.79^{a}
Primal cuts yield, kg	277.74±25.13^{b}	290.32±27.27^{a}	297.19±29.47^{a}
Fat yield, kg	83.07±12.35^{c}	101.76±15.19^{b}	127.35±17.86^{a}
Bone yield, kg	43.09±4.93	43.21±5.43	43.39±4.77

[a-f] Means within the same row with different superscript are statistically different ($p<0.05$)

[1)]Yield index : (11.06398 – [1.25149 × Backfat thickness (mm)] + [0.28293 × Ribeye area (cm^2) + [0.54768 × Carcass cold weight (kg)]) ÷ (Carcass cold weight (kg) × 100)

[2)]Marbling Score: 1-trace, 9-very abundant

Table 6. Least square means (±SD) of ten major primal cuts yields according to yield grade

Item	Yield grade[1)]		
	A (n=74)	B (n=215)	C (n=114)
Tenderloin, kg	5.97±0.58	6.10±0.65	6.04±0.60
Sirloin, kg	33.78±3.72[b]	34.90±3.64[a]	35.78±4.11[a]
Strip loin, kg	8.58±1.05	8.78±1.02	8.86±1.14
Chuck, kg	15.30±2.34	15.79±2.31	15.67±2.52
Shoulder, kg	24.23±2.58	24.73±2.71	24.97±2.68
Bottom round, kg	23.04±2.40	23.03±2.58	23.34±2.69
Top round, kg	35.44±3.62[b]	35.90±4.00[ab]	36.89±4.23[a]
Brisket	43.41±5.02[b]	45.64±5.20[a]	45.55±5.73[a]
Shank, kg	20.29±1.87[b]	20.61±2.42[b]	21.51±2.56[a]
Rib, kg	65.36±6.80[c]	72.47±7.88[b]	76.25±9.12[a]

[a-f] Means within the same row with different superscripts are statistically different ($p<0.05$)

Table 7. Correlation coefficients between carcass traits and Hanwoo primal cuts yield

Trait	Tenderloin, kg	Sirloin, kg	Strip loin, kg	Chuck, kg	Shoulder, kg	Bottom round, kg	Top round, kg	Brisket, kg	Shank, kg	Rib, kg
Slaughter age, month	0.20***	0.22***	0.18***	0.17***	0.21***	0.20***	0.23***	0.16***	0.14**	0.17***
Market weight, kg	0.67***	0.77***	0.72***	0.67***	0.75***	0.72***	0.77***	0.70***	0.55***	0.84***
Carcass cold weight, kg	0.70***	0.81***	0.75***	0.69***	0.77***	0.73***	0.78***	0.73***	0.55***	0.89***
Backfat thickness, mm	0.02	0.20***	0.16***	0.06***	0.09	0.05	0.12*	0.11*	0.15**	0.42***
Ribeye area, cm^2	0.50***	0.63***	0.71***	0.47***	0.52***	0.56***	0.55***	0.46	0.36***	0.45***
Dressing percentage, %	0.30***	0.37***	0.32***	0.27***	0.30***	0.25***	0.26***	0.32***	0.19***	0.44***
Yield index	-0.04	-0.19***	-0.11*	-0.08	-0.12*	-0.06	-0.13**	-0.15**	-0.16**	-0.47***
Marbling score, no.	-0.04	0.21***	0.15**	-0.04	-0.04	-0.07	-0.02	-0.07	-0.04	0.17***

* p<0.05; ** p<0.01; *** p<0.001; 2) Marbling Score: 1-trace, 9-very abundant

Table 8. Multiple regression analysis and contribution of carcass traits and primal cuts of Hanwoo

Dependent variable, kg	Independent variable				R^2	Contribution, %		
	Intercept	CCW, kg	BFT, mm	REA, cm^2		CCW, kg	BFT, mm	REA, cm^2
Tenderloin, kg	1.18639	0.01042	-0.04346	0.00889	0.61***	75.17	22.53	2.30
Sirloin, kg	-0.16619	0.06123	-0.13913	0.10673	0.74***	82.18	7.31	10.51
Strip loin, kg	-1.15726	0.01357	-0.03729	0.04861	0.71***	59.87	7.80	32.34
Chuck, kg	-2.1031	0.03897	-0.14236	0.02521	0.57***	80.15	18.44	1.41
Shoulder, kg	2.49694	0.04843	-0.16563	0.03104	0.69***	82.04	16.54	1.42
Bottom round, kg	1.656	0.04233	-0.16392	0.05302	0.66***	75.50	19.52	4.98
Top round, kg	1.96606	0.07005	-0.21784	0.06382	0.69***	83.22	13.87	2.91
Brisket	4.66717	0.09262	-0.27806	0.03161	0.59***	86.18	13.39	0.42
Shank, kg	7.00651	0.02923	-0.06035	0.01698	0.32***	91.94	6.76	1.31
Rib, kg	1.26539	0.16837	0.01077	-0.0535	0.79***	99.57	0.01	0.42

* $p<0.05$; ** $p<0.01$; *** $p<0.001$; CCW, carcass cold weight; BFT, backfat thickness; REA, ribeye area

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