Research Square

Preprints are preliminary reports that have not undergone peer review. They should not be considered conclusive, used to inform clinical practice, or referenced by the media as validated information.

WITHDRAWN: Market weight, slaughter age, and yield grade to determine economic carcass traits and primal cuts yield of Hanwoo beef

Ki-Mun Kwon
Korea Institute for Animal Products Quality Evaluation
Hwa-Eun Jeon
Korea Institute for Animal Products Quality Evaluation
Seung-Ju Han
Korea Institute for Animal Products Quality Evaluation
Hee-Chan Woo
Korea Institute for Animal Products Quality Evaluation
Sung-Min Heo
Korea Institute for Animal Products Quality Evaluation
Hyoung Ki Hong
Chungbuk National University
Kim Margarette C. Nogoy
Chungbuk National University
Seong Ho Choi
seongho@cbnu.ac.kr

Chungbuk National University https://orcid.org/0000-0001-8869-0218

Research

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

Posted Date: November 3rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1029292/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Version of Record: A version of this preprint was published at Journal of Animal Science and Technology on January 1st, 2022. See the published version at https://doi.org/10.5187/jast.2021.e136.

EDITORIAL NOTE:

The full text of this preprint has been withdrawn by the authors while they make corrections to the work. Therefore, the authors do not wish this work to be cited as a reference. Questions should be directed to the corresponding author.

Abstract

Objective

This study was conducted to evaluate the relationship between market weight, slaughter age, yield grade, and primal cut yield in Hanwoo.

Methods

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.

Findings

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 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.

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 (Hwang et al., 2010; Jeremiah et al., 2003). 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 (Ministry of Food and Drug Safety, 2014). 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 (Jung et al., 2015), and Seo et al. (2021) 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 (Ministry for Food, Agriculture, Forestry, 2007). 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 (Korean Institute for Animal Products Quality Evaluation, 2016). Marbling score and carcass weight steadily increased with the increasing age of slaughter (26, 28, and 30 months) (Ki Yong Chung et al., 2015). 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 (Park et al., 2002) to 694 kg in 2011 (Korea Institute for Animal Products Quality Evaluation, 2011). The average feeding cost of Hanwoo has increased from 2,170,000 won/head in 2010 to 2,982,000 won/head in 2016 (K.Y. Chung et al., 2018). 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 age of Hanwoo at slaughter to primal 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 Evaluations And Measurements

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°C), carcass cold weight was measured and dressing percentage was calculated, and the left side of the carcass was ribbed between the last rib 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. Yield grade was determined by the carcass cold weight, adjusted backfat thickness, and the ribeye area.

Yield index was calculated by the following equation:

(11.06398 – [1.25149 × Backfat thickness (mm)]

+ [0.28293 × Ribeye area (cm^2)

+ [0.54768 × Carcass cold weight (kg)])

÷ (Carcass cold weight (kg) ×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 (Ministry of Food and Drug Safety, 2014). 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 (SAS Institute Inc., 2014). 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 have been shown in Table 1. Results showed that the carcass cold weight, ribeye area, and backfat thickness increased as the market weight of Hanwoo increased ($p<0.05$). The meat yield index showed a tendency to decrease as the market weight increased ($p<0.05$) as similarly observed in a previous report that there was a significant decrease in yield index as the Hanwoo market weight increased (J. M. Lee et al., 2008). The lowest market weight of 651 kg has shown the highest meat yield index

of 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 (Ríos-Utrera et al., 2005), it did not show significant differences among the different market weights of Hanwoo. The marbling score of Hanwoo beef increased significantly as the market weight increased, in which the highest score of 3.96 and a lowest of 3.35 were observed. Consistent with the study of Kim et al. (2018), the primal cuts yield, fat weight, and bone weight yield significantly increased with increasing market weight ($p<0.05$). Specifically, the lowest primal cuts yield of 247.65 kg was observed at the lowest market weight (651≥ 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 ($p<0.05$).

Table 1

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

Carcass Traits	Market weight, kg					
	651≥	651-700	701-750	751-800	801-850	851≤
	n=23	n=69	n=88	n=113	n=63	n=47
Age of slaughter, 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}
Carcass cold weight, 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}

$^{a-f}$ 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 ( ) ×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(㎏)					
	651≥	651-700	701-750	751-800	801-850	851≤
	n=23	n=69	n=88	n=113	n=63	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}

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

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 (Boleman et al., 1998; Miller et al., 1997), but a high positive correlation in slaughter weight and marbling with ribeye area was found according to the Hanwoo grading system (Moon et al., 2003). 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 have been shown in Table 3. Results showed that the market weight and carcass cold weight increased from 25 months to 30-31 months, but a steady high market weight and carcass cold weight were observed from 30-31 months to 34 months. Similar to the report of Yoon et al. (2013), the increase in carcass cold weight has stopped progressing after reaching 28 months of age. The ribeye area increased from 25 months to 26-27 months but has stopped increasing upon reaching 28-29 months. The backfat has shown consistent thickness from 25 months to 32-33 and has slightly increased at the of 34 months or older. In the Japanese black cattle, a similar observation was found where carcass weight, ribeye area, and backfat thickness did not show significant difference at slaughter age of 30 to 34 months of age (Iwamoto et al., 2009). The marbling score of the Hanwoo beef differing in slaughter age ranged from 3.47 to 4.01 and have not shown significant differences. Lean meat production (primal cuts yield) and 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 have been 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. Tenderloin, sirloin, shoulder, bottom round, and top round increased from 25 months to 28-29 months and slightly increased more from then on 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. These observations signify that a slaughter age of 28-29 months is 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 Yoon et al. (2013) and Kim et al. (2005) also suggested that at 28 and 29-month old endpoints, respectively, is a suitable slaughter age for Hanwoo. Slaughtering at 28-29 months could be beneficial in reducing production costs without sacrificing the yield grade of Hanwoo beef.

Table 3

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

Trait	Slaughter age, month					
	25≥	26~27	28~29	30~31	32~33	34≤
	n=15	n=87	n=96	n=106	n=71	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}
Carcass cold weight, 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}
Ribeye area, 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}
Backfat thickness, 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}
Dressing percentage, %	58.96±1.31	58.99±1.66	59.08±1.72	59.20±1.85	58.75±1.86	58.94±1.90
Marbling score[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
Primal cuts yield, 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}

$^{a-f}$ 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 ( ) ×100)

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

Table 4
Least square means (±SD) of ten major primal cuts yields according to Hanwoo market weight

Item	Slaughter age, month					
	25≥	26~27	28~29	30~31	32~33	34≤
	n=15	n=87	n=96	n=106	n=71	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}

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

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 ribeye area, backfat thickness, and carcass weight, and with grade A as the highest. Changes in the economic carcass characteristics according to the yield grade of Hanwoo beef have been shown in Table 5. Carcass cold weight and backfat thickness were found to decrease as the grade increased ($p<0.05$), while the ribeye area did not show a significant difference with yield grade. The yield index 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 decreased carcass weight increased backfat thickness, and increased yield index was also consistent with findings of previous studies (Cho et al., 2020; J. Lee et al., 2011; Rhee et al., 2003). 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 Yoon et al. (2013). 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 (Korean Institute for Animal Products Quality Evaluation, 2016). 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.

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

Trait	Yield grade[1)]		
	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 ( ) ×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 ($p<0.05$)

Correlation Of Carcass Yield Traits With Primal Cuts Yield

The simple correlation between the carcass traits and the primal cuts yield has been 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). Carcass cold weight correlation 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 to reports of Lee et al. (2013) and Seo et al. (2021). The backfat thickness 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 ribeye area 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, strip loin at 0.15, and ribs at 0.17 (p<0.001). Among the ten primal cuts, tenderloin, sirloin, strip loin, and ribs have shown the highest overall acceptability (Jung et al., 2015). 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 prolonging or shortening the slaughter age or by increasing and decreasing market weight for the slaughter 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.

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	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

Multiple Regression Analysis

The regression analysis and the contribution of carcass traits according to primal cuts yield have been 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 carcass weight and negative regression coefficients with backfat thickness. The ribeye area also

showed a positive regression coefficient in all prime cuts except the ribs. Among the carcass traits, the highest contribution predicting the production yield of all the prime cuts of Hanwoo beef was observed in carcass cold weight.

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

Dependent variable, kg	Independent variable				R-Square	Contribution, %		
	Intercept	CCW, kg	BFT, mm	RBA, cm^2		CCW, kg	BFT, mm	RBA, 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; RBA, ribeye area								

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 28-29 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 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.

Declarations

Acknowledgments

This study was funded by the Korea Institute for Animal Products Quality Evaluation.

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.

Author's contributions

Concept: Ki-Mun Kwon, Kim Margarette C. Nogoy, Seong Ho Choi

Data curation: Ki-Mun Kwon, Hwa-Eun Jeon, Seung-Ju Han, Hee-Chan Woo, Sung-Min Heo, Hyoung Ki Hong

Formal Analysis: Ki-Mun Kwon

Methodology: Ki-Mun Kwon, Hwa-Eun Jeon, Seung-Ju Han, Hee-Chan Woo, Sung-Min Heo, Hyoung Ki Hong

Validation: Kim Margarette C. Nogoy, Seong Ho Choi

Writing: original draft: Ki-Mun Kwon, Kim Margarette C. Nogoy

Writing: review & editing: Seong Ho Choi

Authors' information

Ki-Mun Kwon[1], Hwa-Eun Jeon[1], Seung-Ju Han[1], Hee-Chan Woo[1], Sung-Min Heo[1], Hyoung Ki Hong[2], Kim Margarette C. Nogoy[2], Seong Ho Choi[2]

Author's details

[1]Korea Institute for Animal Products Quality Evaluation, Sejong 30100, Korea

[2]Department of Animal Science, Chungbuk National University, Cheongju 28644, Korea

References

Boleman, S. L., Boleman, S. J., Morgan, W. W., Hale, D. S., Griffin, D. B., Savell, J. W., Ames, R. P., Smith, M. T., Tatum, J. D., Field, T. G., Smith, G. C., Gardner, B. A., Morgan, J. B., Northcutt, S. L., Dolezal, H. G., Gill, D. R., & Ray, F. K. (1998). National Beef Quality Audit-1995: Survey of Producer-Related Defects and Carcass Quality and Quantity Attributes. *Journal of Animal Science*, *76*(1), 96–103. https://doi.org/10.2527/1998.76196x

Cho, H., Jung, Y.-B., Kim, B.-D., Jung, S., & Seo, S. (2020). Assessment of the Effects of Carcass Traits and Slaughter Age on the Carcass Grades of Hanwoo Steers Based on the Revised Grading System of Beef Carcasses. *Journal of Agriculture & Life Science*, *54*(2), 69–76. https://doi.org/10.14397/jals.2020.54.2.69

Chung, K.Y., Lee, S. H., Cho, S. H., Kwon, E. G., & Lee, J. H. (2018). Current situation and future prospects for beef production in South Korea - A review. *Asian-Australasian Journal of Animal Sciences*, *31*(7), 968–975. https://doi.org/10.5713/ajas.18.0201

Chung, Ki Yong, Chang, S. S., Lee, E. M., Kim, H. J., Park, B. H., & Kwon, E. G. (2015). Effects of high energy diet on growth performance, carcass characteristics, and blood constituents of final fattening Hanwoo steers. *CNU Journal of Agricultural Science*, *42*(3), 261–268.

Hwang, Y. H., Kim, G. D., Jeong, J. Y., Hur, S. J., & Joo, S. T. (2010). The relationship between muscle fiber characteristics and meat quality traits of highly marbled Hanwoo (Korean native cattle) steers. *Meat Science*, *86*(2), 456–461. https://doi.org/10.1016/j.meatsci.2010.05.034

Iwamoto, E., Oka, A., & Iwaki, F. (2009). Effects of the fattening period on the fatty acid composition of fat deposits and free amino acid and inosinic acid contents of the longissimus muscle in carcasses of Japanese Black steers. *Animal Science Journal*, *80*, 411–417.

Jeremiah, L. E., Gibson, L. L., Aalhus, J. L., & Dugan, M. E. R. (2003). Assessment of palatability attributes of the major beef muscles. In *Meat Science* (Vol. 65, Issue 3, pp. 949–958). https://doi.org/10.1016/S0309-1740(02)00307-8

Jung, E. Y., Hwang, Y. H., & Joo, S. T. (2015). Chemical Components and Meat Quality Traits Related to Palatability of Ten Primal Cuts from Hanwoo Carcasses. *Korean Journal for Food Science of Animal Resources*, *35*(6), 859–866. https://doi.org/10.5851/kosfa.2015.35.6.859

Kim, J. H., Ba, H. V., Seong, P. N., Kim, Y. S., Kang, S. M., Cho, S. H., Moon, S. S., Kang, S. J., Park, B. Y., & Seo, H. W. (2018). Carcass Characteristics and Primal Cuts Yields by Live Weight of Hanwoo Steers in Gyeongbuk Province. *Journal of Agriculture and Life Science*, *52*(2), 151–167.

Kim, K. H., Lee, J. H., Oh, Y. G., Kang, S. W., Lee, S. C., Park, W. Y., & Ko, Y. D. (2005). The Optimal TDN Levels of Concentrates and Slaughter Age in Hanwoo Steers. *Journal of Animal Science and Technology*, *47*(5), 731–744. https://doi.org/10.5187/jast.2005.47.5.731

Korea Institute for Animal Products Quality Evaluation. (2011). *Marketing Livestock and Meat in the Korea. Examination and Research Report*. http://www.ekapepia.or.kr.

Korean Institute for Animal Products Quality Evaluation. (2016). *Annual Report for Animal Products Research*. http://www.ekapepia.com/home/homeIndex.do

Lee, J., Choi, S., Dang, C., Kang, S. N., & Kim, N. (2011). The effect of carcass traits on economic values in Hanwoo. *Korean Journal for Food Science of Animal Resources*, *31*(4), 603–608. https://doi.org/10.5851/kosfa.2011.31.4.603

Lee, J. G., Lee, S. S., Cho, K. H., Cho, C., Choy, Y. H., Choi, J. G., Park, B., Na, C. S., & Choi, T. (2013). Correlation Analyses on Body Size Traits, Carcass Traits and Primal Cuts in Hanwoo Steers. *Journal of Animal Science and Technology*, *55*(5), 351–358. https://doi.org/10.5187/jast.2013.55.5.351

Lee, J. M., Hah, K. H., Kim, J. H., Cho, S. H., Seong, P. N., Jung, M. O., Cho, Y. M., Park, B. Y., Kim, D. H., & Ahn, C. N. (2008). Study on the carcass yield grade traits and prediction of retail product weight in Hanwoo Beef. In *Korean Journal for Food Science of Animal Resources* (Vol. 28, Issue 5, pp. 604–609). https://doi.org/10.5851/kosfa.2008.28.5.604

Miller, M. F., Kerth, C. R., Wise, J. W., Lansdell, J. L., Stowell, J. E., & Ramsey, C. B. (1997). Slaughter Plant Location, USDA Quality Grade, External Fat Thickness, and Aging Time Effects on Sensory Characteristics of Beef Loin Strip Steak. *Journal of Animal Science*, *75*(3), 662–667. https://doi.org/10.2527/1997.753662x

Ministry for Food, Agriculture, Forestry, and F. (MFAFF). (2007). *Processing standard for meat products act: Grading, fabrication and cutting of beef carcass*.

Ministry of Food and Drug Safety. (2014). *Method for labeling and division of beef and pork meat*.

Moon, S. S., Hwang, I. H., Jin, S. K., Lee, J. G., Joe, S. T., & Park, G. B. (2003). Carcass traits determining quality and yield grades of Hanwoo steers. *Asian-Australasian Journal of Animal Sciences*, *16*(7), 1049–1054. https://doi.org/10.5713/ajas.2003.1049

Park, G. B., Moon, S. S., Ko, Y. D., Ha, J. K., Lee, J. G., Chang, H. H., & Joo, S. T. (2002). Influence of slaughter weight and sex on yield and quality grades of Hanwoo (Korean native cattle) carcasses. *Journal of Animal Science*, *80*(1), 129–136. https://doi.org/10.2527/2002.801129x

Rhee, Y. J., Seok, H. K., Kim, S. J., & Song, Y. H. (2003). Prediction of Carcass Yield by Ultrasound in Hanwoo. *Journal of Animal Science and Technology*, *45*(2), 335–342. https://doi.org/10.5187/jast.2003.45.2.335

Ríos-Utrera, A., Cundiff, L. V., Gregory, K. E., Koch, R. M., Dikeman, M. E., Koohmaraie, M., & Van Vleck, L. D. (2005). Genetic analysis of carcass traits of steers adjusted to age, weight, or fat thickness slaughter endpoints. *Journal of Animal Science*, *83*(4), 764–776. https://doi.org/10.2527/2005.834764x

SAS Institute Inc. (2014). *SAS User's Guide: Version 9.3*.

Seo, H. W., Van Ba, H., Seong, P. N., Kim, Y. S., Kang, S. M., Seol, K. H., Kim, J. H., Moon, S. S., Choi, Y. M., & Cho, S. (2021). Relationship between body size traits and carcass traits with primal cuts yields in Hanwoo steers. *Animal Bioscience*, *34*(1), 127–133.

https://doi.org/10.5713/ajas.19.0809

Yoon, J. H., Won, J. Il, Lee, K. S., Kim, J. B., & Lee, J. K. (2013). Estimation of Reasonable Market Month of Age for Hanwoo Steer. *Journal of Animal Science and Technology*, *55*(5), 405–416. https://doi.org/10.5187/jast.2013.55.5.405