Keys to production and processing of Hanwoo beef: A perspective of tradition and science

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Implications

- Hanwoo is Korean native cattle historically raised mainly in the Korean Peninsula with maintained stable traits and blood lineage.
- In the Korean market, Hanwoo beef is enthusiastically preferred to imported beef despite of its relatively high price, as Korean consumers believe that Hanwoo beef is fresher and has better quality than imported beef according to survey results.
- Hanwoo beef can be characterized by its highly marbled fat (about 24% intramuscular fat content in loin muscles with 1++ quality grade), thin muscle fibers, minimal connective tissues, and the characteristic flavor.
- The quality traits and the nutritative composition of Hanwoo beef are different from beef from Australian Angus.
- Improving marbling scores and decreasing overall production cost are important goals for Korean cattle industry. Thus, caring and feeding strategies are programmed for these purposes.

Key words: beef, caring and feeding strategy, composition, Hanwoo, marbled fat, quality

Hanwoo: Its Impact on Korean Beef Industry

Hanwoo is a type of Korean native cattle which have been raised in the Korean Peninsula since 2000 B.C. In the ancient Agricultural Age, Hanwoo was an important draft tool or sometimes an object of sacrificial rite. Due to their limited number and religious and political issues in Korea, utilization of Hanwoo cattle as an edible meat had been minimal. Full-scale production of Hanwoo as meat-type cattle has occurred since 1960s with the rapid growth of the Korean economy. Thus, eating Hanwoo beef as a main meat source has a very short history, despite the present meat consumption scale in Korea.

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Figure 1. A picture of Hanwoo (source: National Institute of Animal Science, RDA).

Since Hanwoo cattle have maintained stable traits through pure breeding, the current blood lineage is very valuable and is spread out mainly in the Korean Peninsula (Kim and Lee, 2000). Four types of Korean native cattle exist currently in Korea, each with different coat colors: brown (Hanwoo), black face (Heugu), black (Jeju Black), and tiger color (Chikso). The brown coat color is the most common type of Hanwoo (Figure 1).

Hanwoo is known to have relatively superior reproduction abilities but inferior abilities to produce meat and milk because of their slow growth rate and milking capacity. Thus, the Korean cattle industry has aimed to improve meat production ability and to increase the cattle number to meet the demand of the growing beef market in Korea (Kim and Lee, 2000). Before the 1980s, carcass yield was considered more important than meat quality because the overall beef supply had been insufficient in Korea. As the economic level in Korea has improved, the demand for meats has increased and more palatable meats have been preferred. The per capita meat consumption in Korea has drastically increased from 14 kg in 1985 to 40 kg in 2010 and beef consumption from 3 kg to 12 kg (KAPE, 2011). Hanwoo beef is well known for its highly marbled fat, relatively thin mus-

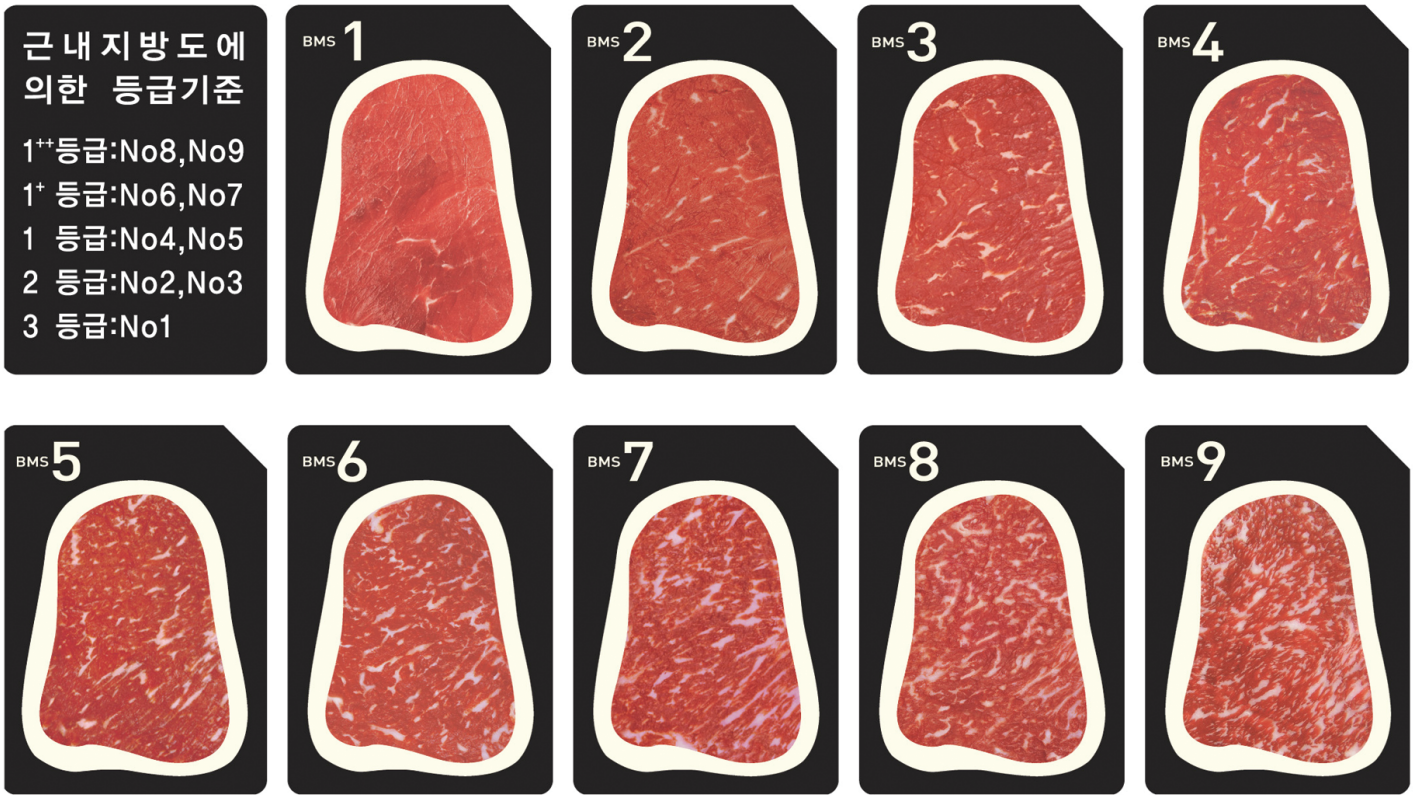

Figure 2. Beef marbling standard (BMS) used for the estimation of quality grade in Korean carcass grade system (source: Korean Institute for Animal Products Quality Evaluation; http://www.ekape.or.kr/view/eng/system/beef.asp). *BMS 1, QG 1; BMS 2 and 3, QG 2; BMS 4 and 5, QG 1; BMS 6 and 7, QG 1+; BMS 8 and 9, QG 1++*

cle fibers, and minimal content of connective tissues (Kim et al., 1994). Cho et al. (2005) reported that Hanwoo steer had less subcutaneous fat depth with greater ossification scores and marbling scores measured by USDA scoring systems than those of the Australian Angus, which were 24 months old at slaughter (Table 1).

In 2011, about 3 million head of beef cattle were being raised in Korea. The total number of slaughtered cattle was 852,000, including 720,000 Hanwoo cattle, 37,000 Holstein cows, and 94,000 Holstein heifers and bulls. The number of cattle farming households was 160,000 (KAPE, 2011). Nevertheless, Korea is only a 42.8% self-sufficient nation in beef market, the rest imported from Australia, USA, New Zealand, Mexico, and Canada, resulting in Korea being the 4th largest global importer of beef (KMTA, 2011). Hanwoo beef is enthusiastically preferred over imported beef in Korean markets, despite its price being twice as expensive, as Korean consumers believe that Hanwoo beef is fresher and has better quality than imported beef (Kim et al. 2000; Han et al., 2010).

Table 1. Carcass traits of Korean Hanwoo and Australian Angus (n = 18 each carcasses)

Carcass traits*	Korean Hanwoo	Australian Angus
Carcass weight, kg	371 ± 38†	386 ± 25.3
Fat depth (12/13th rib, mm)	8.8 ± 3.1	15.7 ± 4.81
Ossification score (USDA)‡	206 ± 22	162 ± 19
Marbling scores (USDA)§	593 ± 60	362 ± 66
Intramuscular fat, %	11.29 ± 3.36	5.72 ± 2.64
Ultimate pH	5.46 ± 0.07	5.45 ± 0.03

* Data from Cho et al. (2005), Hanwoo and Angus slaughtered at 24 months and Longissimus muscle used for trait analysis.

† Mean ± standard deviation.

‡ 100 (low ossification) – 590 (great ossification) by Handbook of Australian Meat (2005).

§ 100 (low marbling) – 1100 (great marbling) by Handbook of Australian Meat (2005).

How Is Hanwoo Beef Evaluated?

Korea's carcass grading system was established in 1992, which presently consists of three levels of "yield grade (**YG**)" evaluating meat amount (A, B, and C) and five levels of "meat quality grade (**QG**)" (1++, 1+, 1, 2, and 3; KAPE, 2012). Although quality grade is estimated by several factors such as marbling score, meat color, fat color, firmness and texture of lean meat, and maturity of the exposed *Longissimus dorsi* (**LD**) muscle at the 13th rib interface (NLCF, 1998), marbling score is the most dominating determinant. Since Korean consumers have an extraordinary preference for high marbled meats, beef grading has also been made based on marbling score. Marbling score is determined using the Beef Marbling Standard (**BMS**). The BMS score of 8 or 9 (above abundant) is the marbling degree for the best QG 1++ (Figure 2).

Quality Grade of Hanwoo Beef

Hanwoo beef with QG 1++ or 1+ is considered a premium class of beef in Korea (Kim et al., 1994). Of Hanwoo cattle slaughtered in 2011, 9.2% were QG 1++, 22.6% QG 1+, and 30.6% QG 1 (KAPE, 2011). Kim and Lee (2003) reported that Hanwoo loins with QG 1++ had the greatest fat contents whereas the moisture content was greatest in beef graded QG

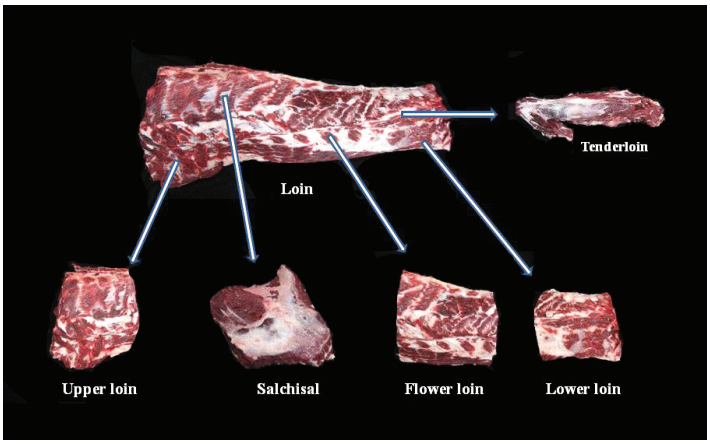

Figure 3. A picture of retail cuts from a loin cut (source: National Institute of Animal Science, RDA).

3. It is generally accepted that percentages of intramuscular fat (**IMF**) and moisture are inversely related (Park et al., 2000). Cho et al. (2010) also presented the chemical composition of five representative cuts from Hanwoo beef with different carcass quality grade. The loins with QG 1++ had 21.5% intramuscular fat contents, followed by QG 1+ (17.6%), QG 1 (11.0%), and QG 2 (6.6%; Table 2).

Park et al. (2000) reported that beef loins with the greatest intramuscular fat had greater tenderness, juiciness, and flavor scores. Parrish et al. (1981) reported that the marbling had a significantly positive correlation with the palatability. Tenderness was positively associated with intramuscular fat content in Angus *Longissimus* muscles with 3.89 ± 1.54% fat content (Seideman and Koohmaraie, 1987). Shear values of LD muscles were significantly lower for Hanwoo beef with QG 1++ (3.5 kg) compared with QG 2 (4.9 kg). This would support a simple mechanism for the effect of intramuscular fat on tenderness score, such as the dilution of a more dense muscle matrix with less dense fat, as proposed by Miller (1994).

What Is the Characteristic Quality of Hanwoo Beef?

Although the appearance, freshness, and nutritional values of meats affect purchase decisions, eating quality of meats is the most decisive criterion (Grunert et al., 2004). More diverse beef cuts and by-products are available in the Korean beef market. There are 10 wholesale cuts and 39 retail cuts to distribute (MIFAFF, 2007), and five different retail cuts are available from the loin (Figure 3). Each cut has its own unique composition and eating properties. In certain local markets, more than 100 unique cuts are sold.

The sensory properties were evaluated and compared with Hanwoo beef and imported beef from the USA and Australia. Hanwoo beef with QG 1++ and 1+ had greater scores in tenderness, juiciness, flavor, and overall likeness of LD muscles than imported beef. Many workers have reported that palatability generally improves as marbling increases (Savell et al., 1987; Tatum et al., 1980), while Jones et al. (1991) also reported that the degree of IMF had no effect on overall beef tenderness, flavor intensity, or desirability, but the beef was juicier in slight degrees of IMF than in trace amounts. Korean consumers decided their overall acceptability of Hanwoo beef are as follows: weights of tenderness 55%, juiciness 18%, and flavor-likeness 27% (Cho et al, 2010). Oliver et al. (2006) reported that the panel preference for meat must have depended on their previous cultural experience and eating habits. Korean consumers were most accustomed to the flavor and texture of Hanwoo beef that was produced in feedlot conditions and great intramuscular fat content while the Australian consumers were used to grass-fed beef.

What Is the Chemical Composition of Hanwoo Beef?

Korean consumers are very interested in the origin, nutritional value, and safety issues of what they eat. In this respect, the chemical composition is one of the important features of meat quality. Generally, meat composition of beef can be varied depending on breed, sex, cutting, and slaughtering methods.

General Composition

Hanwoo and Australian Angus beef slaughtered at 24 months showed similar carcass weights and ultimate pH values (Table 1). There were wide ranges of intramuscular fat content with 2.8 to 21.0% in the Hanwoo *Longissimus* muscles. Although Elmore et al. (2004) reported that cereal-based, energy dense diets lead to heavier and fatter cattle than forage-based diets, the carcass weights of Australian Angus and Hanwoo were similar at the same age (Cho et al., 2005). Hanwoo carcasses had less subcutaneous fat depth, with higher ossification scores and marble scores when measured by the Australian scoring system than those of the Australian Angus carcasses. The average intramuscular fat content of Hanwoo loin was 11.3% while that of Australian Angus was 5.7% in the study.

Protein content of Hanwoo beef loins at Korean QG 1+ and 1 was greater than the Australian Angus and crossbred in loin and strip loin but no difference was found in top round and chuck tender. The fat content

Table 2. Chemical composition, pH, cooking loss, water holding capacity, color, and Warner–Bratzler shear force for Hanwoo steer *Longissimus* (n=72 carcasses for each treatment)*

	Quality Grade			
	1++	1+	1	2
pH	5.51 ± 0.02†	5.54 ± 0.02	5.58 ± 0.02	5.53 ± 0.02
Protein, %	16.53 ± 0.47	18.79 ± 0.31	18.61 ± 0.56	18.71 ± 0.11
Fat, %	21.48^{a} ± 0.89‡	17.61^{b} ± 0.36	11.02^{c} ± 0.63	6.60^{d} ± 0.74
Moisture, %	60.93^{b} ± 1.68	63.52^{b} ± 0.67	69.45^{ab} ± 0.97	73.68^{a} ± 1.21
CIE L*	42.05 ± 0.75	40.27 ± 0.74	39.48 ± 0.83	40.8 ± 1.71
CIE a*	24.04 ± 0.6	24.95 ± 0.56	23.58 ± 0.84	24.53 ± 1.73
CIE b*	12.74 ± 0.47	13.69 ± 0.38	13.25 ± 0.47	13.93 ± 0.95
Warner-Bratzler shear force(kg) during aging periods				
0 day	3.45^{b} ± 0.16	3.82^{ab} ± 0.21	4.00^{ab} ± 0.23	4.85^{a} ± 0.26
14 day	1.95 ± 0.11	2.51 ± 0.18	2.40 ± 0.22	2.57 ± 0.52

*Data from Cho et al. (2005), Hanwoo and Angus slaughtered at 24 months and *Longissimus* muscle used for trait analysis.

† Mean ± standard deviation.

‡ Means in the same row with different letters are significantly different ($P < 0.05$).

of Hanwoo loin with Korean QG 1+ was 17.0% while those of Australian Angus and crossbred were 10.6 and 9.2% respectively, a significant finding (Cho et al., 2011). There was no difference found in mineral content between beef of Hanwoo and Angus except for top round, where the content of Zn was greater in Angus (Cho et al., 2011). The eye of round had the least cholesterol (26.7 mg/100 g) and that of short plate was the greatest cholesterol content (31.1 mg/100 g) across cuts evaluated. Rhee et al. (1982) reported that the cholesterol content of beef ranged from 55 to 66 mg/100 g and no difference was found among different cuts. Total calories of Hanwoo beef ranged from 1,523 to 1,764 cal/g between 10 different cuts (Cho et al., 2007).

Amino Acids

Glutamate presented the greatest amount of amino acids in all of the different cuts of Hanwoo beef. Loin had the least total amino acid content in Hanwoo beef (Cho et al., 2008a). Free amino acids and peptides produced during aging affect the flavor and taste of meat. Glutamate and alanine showed 276 to 536 mg/100 g and 130 to 175 mg/100 g, respectively, and were greater than the other amino acids in all different cuts (Cho et al., 2008b). In beef of Hanwoo bulls, a similar trend was found with 94 to 216 mg/100 g of glutamate and 155 to 200 mg/100 g of alanine (Cho et al., 2007).

Fatty Acids and Volatiles

It has been shown that fatty acid composition varies between different breeds (Zembayashi and Nishimura, 1996; Yang et al., 1999) and that this has an effect on palatability factors of beef, particularly in the Japanese Wagyu (Xie et al., 1996) and Hanwoo (Cho et al., 2005) breeds. The fatty acid composition of Hanwoo beef was different from that of Australian Angus beef (Table 3). Angus beef had significantly higher *n-3* polyunsaturated fatty acids (**PUFA**) while Hanwoo beef contained greater *n-6* PUFA in three different muscles (Cho et al., 2005), which can be attributed to different feeding conditions (Table 3).

Even though fatty acid profiles of tissues from ruminant animals are not a direct reflection of dietary fat content, the management practices applied to produce Hanwoo beef can have some influence on production of the characteristic high quality beef. The difference in fatty acid composition is a possible attribute to the influence of different diets, forage, and grain feeding, even though the fatty acid profile in ruminants is not a direct reflection of the dietary fatty acid composition due to hydrogenation by rumen microorganisms (Enser et al., 1998). Therefore, it can be easily anticipated that Hanwoo beef has a fatty acid profile characterized by high concentrate-fed animals. The fatty acids in Hanwoo beef had less linolenic acid and greater ratio of *n-6*/*n-3* unsaturated fatty acids compared to the Australian Angus beef (Cho et al., 2005). Cho et al. (2008a) reported that the fatty acid compositions of beef had a significant relationship with the palatability of Korean consumers, and specific types of fatty acids discriminated the palatability based on beef origin. Therefore, the fatty acid compositions of beef impacted the beef preference of Korean consumers.

Hanwoo and imported beef can vary in volatile compounds (Cho et al., 2011). This is especially true for the amounts of hexanal, heptanal, octanal, E-2-octenal, nonenal, E-2-decenal, 2,4-decadienal, 2-undecenal, heptane, and 2-butyl furan, which were greater in LD muscle of Hanwoo beef when compared with those of the imported beef. These results agree with Larick et al. (1998), who reported that grain-fed beef had greater contents of hexanal, 2-heptenal, and 2,4-decadienal, which are all produced from linoleic acid.

Table 3. Comparison of fatty acid composition (% of total lipid) between Hanwoo and Angus *Longissimus* muscles†

Fatty acid‡	Angus§	Hanwoo#	RSD††	Breed F statistic and significance
Total lipid	11.29	5.72	-	-
C14:0	2.56	3.00	0.35	78.24***
C16:0	29.79	28.21	1.85	37.30***
C16:1(n7)	2.70	3.94	1.37	88.19***
C18:0	14.16	9.00	0.89	2180.64**
C18:1(n9)	47.62	52.14	2.26	16.03***
C18:1(n7)	0.24	0.84	1.17	103.40***
C18:2(n6)	1.80	2.11	1.07	260.63***
C18:3(n6)	0.01	0.00	0.06	8.07**
C18:3(n3)	0.21	0.08	0.03	1576.1***
C20:1(n9)	0.24	0.32	0.12	55.49***
C20:2(n6)	0.00	0.01	0.02	29.51***
C20:3(n6)	0.15	0.11	0.11	3.51
C20:4(n6)	0.37	0.25	0.35	10.57*
C20:5(n3)	0.06	0.00	0.05	461.57***
C22:4(n6)	0.00	0.00	0.05	40.75***
C22:5(n3)	0.08	0.00	0.09	324.92***
SFA	46.51	40.20	2.27	486.32***
USFA	53.49	59.79	2.27	486.14***
MUFA	50.80	57.3	2.32	224.02***
PUFA	2.69	2.56	1.51	102.72***
n3	0.35	0.08	0.15	637.65***
n6	2.34	2.48	1.43	178.91***
n6:n3	7.60	30.79	8.56	1695.1***
MUFA:SFA	1.10	1.44	0.15	321.69***
PUFA:SFA	0.16	0.06	0.04	153.69***

*F-ratio statistic (if $P < 0.05$).

** F-ratio statistic (if $P < 0.01$).

*** F-ratio statistic (if $P < 0.001$).

† Data from Cho et al., 2005.

‡ SFA, saturated fatty acids; USFA, unsaturated fatty acids; MUFA, monosaturated fatty acids; PUFA, polyunsaturated fatty acids.

§ Australian Angus.

Korean Hanwoo.

†† Residual standard deviation.

Collagen and Nucleotides

There was no difference among different cuts in soluble and insoluble collagen content, but total collagen content of short plate was the greatest (12.8%) followed by brisket, chuck tender, and chuck roll in Hanwoo beef. Boccard et al. (1979) reported that collagen content of bull was greater than cow and steer and the content of soluble collagen rapidly decreased in ages of 12 to 16 months. Kim et al. (1999) reported that the loin of Hanwoo bull had greater collagen content than that of steer. Similar to most breeds, the Hanwoo top round steaks had greater collagen content


Figure 4. Sawdust bedding (**left**) and a restriction feeding system (**right**) for Hanwoo barn.

than the Hanwoo loin steaks. This is related with the difference of shear force values among different cuts (Cho et al., 2007).

An important taste-related compound in meat are nucleotides, especially inosine-5'-monphosphate (**IMP**), even though it could not guarantee the best taste when the IMP content is the highest (Sakaguchi et al., 1992). The IMP content was less in loin and chuck roll than those of other cuts in Hanwoo bulls. A key taste of meat is umami, which usually comes from glutamic acid and inosinic acid and, especially, the synergistic effect when these two compounds are presented together (Cho et al., 2007). The authors also indicated that the sauce for Western meat soup is usually depended on nucleotides but that of North East Asian countries has a synergistic effect with Kanjang (soy sauce), which has increased glutamic acid.

Caring Strategy for High Quality of Hanwoo Beef

The high quality grade is the most important goal for the improvement of Korean cattle and more attention is being paid on more accumulation of IMF in beef muscles. Although the marbling score increased and reached a plateau at about 24 months of age in Korean native cattle (Kazala et al., 1999; Choi et al., 2002), the timing to be sent in market (marketing age) has been extended for targeting of high BMS. In the early 1980s, the Korean cattle were sent out to the market at about 24 months old (marketing weight of 425 kg), but it has been extended to an average of 31 months (marketing weight of 694 kg) for the fattening of cattle (Park et al., 2002; KAPE, 2011). As the marketing live weight increased, the marbling score eventually increased but average daily gain decreased (Paek et al., 1993). Therefore, the extended marketing age of Hanwoo results in the eventual increase of beef price and is sometimes criticized by people who emphasize more reasonable beef price and nutritional composition. Thus, traditional caring and feeding strategies may be changed by the issues of seeking low fat foods, sustainable farming, and animal welfare.

To improve meat marbling and tenderness, pen size is restricted to minimize animal movement which affects feed consumption. Normally, a pen size of 9 to 10 m^2/head is used for Hanwoo steer with saw dust bedding (Figure 4). Saw dust absorbs moisture in manure and urine and is fermented during drying. To accelerate drying and cooling in the summer, ceiling fans are operated 24 hours a day. Due to the saw dust bedding with ceiling fan, dry and comfortable bedding can be provided without offensive odor.

To produce more desirable beef for the Korean market, careful selections of calves, sex, and castration are made as beef quality fundamentally depends on the genetic traits of the cattle. Fattening steers is more advantageous in the aspect of marbling than fattening bulls. Hong et al. (1996) reported that castration reduced growth rate and retailed cuts but increased body fat. Earlier castration can improve marbling score, but decrease body weight gain and feed efficiency. On the other hand, late castration (such as 12 months of age) can improve the loin *Logissimus* muscle, but decrease marbling score. For these reasons, castration is normally performed at 6 months.

Feeding Strategy for High Quality of Hanwoo Beef

To produce Hanwoo beef to satisfy the Korean consumers, appropriate feeding management is imperative for high quality Hanwoo beef. Even though feeding management is programmed considering many factors such as growth rate, feed efficiency, and disease intolerance of the raised cattle, the accumulation of intramuscular fat in muscle cannot be disregarded. Because there are big margin gaps (~2.5 times between the uppermost and lowest quality grade) for cattle farmers depending on the meat quality grade, most Korean cattle farmers are ultimately interested in specific feed rations or supplements which are more beneficial to get high marbling scores.

Hanwoo cattle are usually fed a high level of concentrate diet at the final stage for the purpose of greater accumulation of intramuscular fat in muscles (Figure 5), which is the most critical point to the Hanwoo cattle industry. Ahn (2000) reported that enough roughage should be fed to cattle during the growing period while concentrates should be fed during both the growing and fattening periods.

The most common feeding program is to provide a restricted amount of concentrate and ad libitum of rice straw as forage at the growing stage. At the finishing stage, the rate of concentrate is raised to 90% and only 10% of rice straw is provided to increase marbling scores. Most of feed resources for concentrate are imported. To increase feed efficiency as well as decrease feed cost, total mixed ration (**TMR**) using agricultural by-products such as soybean curd cake, citrus pomace, apple pomace, and

Figure 5. Appearance of Hanwoo loin muscles with Korean meat quality grade 2 (**top**) and 1++ (**bottom**).

carrot pomace is applied to Hanwoo feed. At growing and early finishing stage, TMR either homemade or purchased is provided at recommended amounts (Figure 4). However, at the late finishing stage, 90% concentrate and 10% rice straw is provided to maximize intramuscular fat depot. In general, feeding of concentrates as a form of compound feed (CP 12 to 13%, TDN 72 to 73%) is restricted to 1.6 to 1.9% of body weight at early fattening stage of Hanwoo steer. At mid fattening stage, more concentrates are introduced while reducing roughage. Then, concentrates (CP 11 to 12%, TDN 73%) are used with a restriction of pasture that is less than 10% of total feed at the late fattening stage.

Conclusion

Hanwoo cattle are Korean native cattle historically raised in the Korean Peninsula. Since Hanwoo cattle have maintained stable traits through pure breeding, the current blood lineage is very valuable and is spread out mainly in the Korea. Although Hanwoo beef is expensive compared with imported beef, Korean consumers enthusiastically prefer it to imported beef as they believe Hanwoo beef is fresher and has better quality. Hanwoo beef can be characterized by its highly marbled fat depot, thin muscle fibers, minimal concentration of connective tissues, and its characteristic flavor. Due to the high preference for high marbled meats, beef grade system in Korea has been made on the basis of marbling score. When Hanwoo beef was compared with the Australian Angus, it showed characteristic compositional and quality differences that should result from genetic and environmental differences between them. Currently, beef price is determined by the quality grade, with the uppermost grade beef costing 2.5 times more than the lowest grade. For this reason, the highly marbled Hanwoo beef is the most important focus to maximize income, and caring and feeding strategies are considered to result in superior meat quality grade with high marbling scores. Thus, the marketing age of Hanwoo has been increasing and a high level of concentrate diet is excessively fed.

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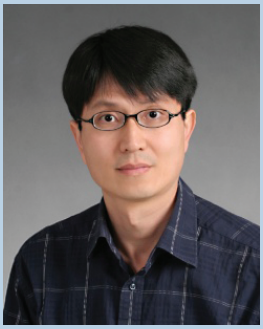

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