

Characteristics and Health Benefit of Highly Marbled Wagyu and Hanwoo Beef

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Abstract

This review addresses the characteristics and health benefit of highly marbled Wagyu and Hanwoo beef. Marbling of Wagyu and Hanwoo beef has been increased in Japan and Korea to meet domestic consumer preferences. Wagyu and Hanwoo cattle have high potential of accumulating intramuscular fat (IMF) and producing highly marbled beef. The IMF content varies depending on the feeding of time, finishing diet, and breed type. IMF increases when feeding time is increased. The rate of IMF increase in grain-fed cattle is faster than that in pasture-fed cattle. Fatty acid composition are also different depending on breeds. Highly marbled Wagyu and Hanwoo beef have higher proportions of monounsaturated fatty acid (MUFA) due to higher concentrations of oleic acid. MUFAs have little effect on total cholesterol. They are heart-healthy dietary fat because they can lower low-density lipoprotein (LDL)-cholesterol while increasing high-density lipoprotein (HDL)-cholesterol. Clinical trials have indicated that highly marbled beef does not increase LDL-cholesterol. This review also emphasizes that high oleic acid beef such as Wagyu and Hanwoo beef might be able to reduce risk factors for cardiovascular disease.

Keywords: Wagyu, Hanwoo, marbling, intramuscular fat, oleic acid

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Introduction

Wagyu and Hanwoo cattle are major beef breeds in Japan and Korea, respectively. Their marbling has been increased over many decades to meet domestic consumer preferences. In both countries, highly marbled beef is greatly prized for traditional meat cooking methods such as Sukiyaki for Japanese and Gogigui for Korean. Because of these demands, the use of heifers and steers instead of bulls, intensive feeding system, and genetic ability of Wagyu and Hanwoo cattle have resulted in greater fat deposition in these breeds compared to European breeds. As intramuscular fat (IMF) improves beef quality at least in juiciness and flavor (Hornsterin and Wasserman, 1987; Wheeler *et al.*, 1994), marbling is an accepted indicator of meat quality. It is assessed in abattoirs by meat graders in various countries, including USA, Australia, Japan,

and Korea.

Like other kinds of foods, meat has three functions: 1) It provides nutrition; 2) It provides deliciousness; and 3) It prevents disease. Although beef has these three functions, the main food in both Japan and Korea is boiled rice while beef is a side dish. Therefore, these two countries have developed the quality of beef rather than its quantity. This is quite different from foreign countries where meat is consumed as a main dish. In Japanese and Korean cuisine, soft and delicious beef with IMF and a good red color are requisites for food cooking methods such as Sukiyaki and Gogigui.

Nowadays, bioscience has given us a new concept on health. In the past, fat was not given a good image in its role towards human health, although fat is an important energy resource for human. Recently, fat has been reported to have fewer adverse effects on health than carbohydrates, especially simple carbohydrates. In fact, meat has played a crucial role in human evolution of a healthy and well balanced diet (Pereira and Vicente, 2013). Furthermore, meat plays a pivotal role in nutritious diets. High quality marbled beef not only has excellent eating quality, but also contains a lot of beneficial fatty acids (Troy *et al.*,

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2016). In this regard, the current paper reviews the characteristics and health benefit of highly marbled beef from Wagyu and Hanwoo cattle.

Wagyu and Hanwoo Cattle

It has well known that Wagyu cattle have high potential of accumulating IMF and producing highly marbled beef. Hanwoo cattle are also known for their high IMF for marbled beef similar to Wagyu beef. Highly marbled Wagyu loin contains more than 40% of IMF, sometimes more than 60% (Horii *et al.*, 2009), while quality grade 1⁺⁺ Hanwoo, the highest quality grade, has approximately 28% of IMF in *longissimus thoracis* muscle (Hwang and Joo, 2016). Wagyu cattle include four types of Japanese cattle: the Black, Brown, Short Horn, and Polled breeds. Numerous studies have investigated the meat quality, quantity, and muscle physiology of crossbreed Wagyu (Japanese Black cattle) in foreign countries (Cafe *et al.*, 2006; Cafe *et al.*, 2009; Greenwood *et al.*, 2006; Greenwood *et al.*, 2009; May *et al.*, 1993). There are also four types of Hanwoo in Korea. They are identified by different coat color: brown (Major Hanwoo), black face (Heukwoo), black (Jeju Heukwoo), and tiger color (Chickso) (Jo *et al.*, 2012). In this review, Wagyu and Hanwoo are used to describe the Japanese Black breed and the brown coat color Hanwoo, respectively.

All four types of Wagyu cattle have played important roles locally and in the history of mixed farming. They also played important roles in the synergies between cattle and crops, especially rice. Farmers gradually began to replace the role of cattle as draft animals and started to use industrial fertilizers approximately 50 years ago. In recent years, Japanese Wagyu cattle have been raised more specifically for beef production. The famous brand name Wagyu not only includes the Japanese Black cattle produced in Japan, but also includes animals or even crossbreed Japanese Black cattle produced in foreign countries such as Australia and the United States. Similarly, the utilization of Hanwoo cattle as an edible meat had been minimal for long time. Full-scale production of Hanwoo as meat-type cattle has started since the 1970s. Because Hanwoo cattle have maintained stable traits through pure breeding, the current blood lineage is very valuable. It is mainly spread in the Korean peninsula (Kim and Lee, 2000). Recently, Hanwoo beef has been reported to have highly marbled IMF similar to Wagyu beef. Especially, Hanwoo beef has relatively thin muscle fiber and minimal content of connective tissues (Kim *et al.*, 1994). It has less

subcutaneous fat depth with greater ossification scores and marbling scores than those of Australian Angus (Cho *et al.*, 2005).

In 2013, a total of 2.64 million heads of cattle were fed for beef production in Japan. Approximately 1.71 million heads were Japanese Black cattle (MAFF, 2013), and approximately 873,400 were Holstein cattle. The number of households raising beef cattle is slowly decreasing in Japan. In 2013, the number of farmers producing beef was 613,000, but 86.5% of these farmers fed less than 50 heads of cattle. The mean body weight and carcass weight of beef at slaughter (26-30 mon of age) were 725 kg and 470 kg, respectively. High performance marbled beef production has caused Japanese Black cattle to comprise the greatest share of Japan's Wagyu cattle population (Albrecht *et al.*, 2011; Gotoh *et al.*, 2009; Gotoh *et al.*, 2014). Recently, the IMF percentage of beef from Japanese Black cattle has an average value of greater than 30% (Albrecht *et al.*, 2011; Horii *et al.*, 2009).

In Korea, approximately 3.5 million beef cattle were raised in 2015. The total number of slaughter cattle was 1,007,000, including 883,593 Hanwoo cattle, 66,485 Holstein cows, and 56,923 Holstein heifers and bulls (KAPE, 2015). The number of cattle farming households was 99,858, including 89,403 Hanwoo farmers (KAPE, 2015). During the last decade, the number of households raising Hanwoo cattle has drastically decreased from 186,000 households in 2006 to 89,403 households in 2015 (KAPE, 2016). The average live and carcass weights of Hanwoo cattle at slaughter (26-30 mon of age) were 719 kg and 430 kg, respectively (KAPE, 2015).

Carcass Grading of Wagyu and Hanwoo

Wagyu carcasses are evaluated by accredited graders from the Japan Meat Grading Association (JMGA) in accordance with beef carcass grading standards. There are nearly 200 accredited graders in Japan. First established in 1988, the present grading system assigns both yield grade (A, B, and C) and meat quality grade (1, 2, 3, 4, and 5) (JMGA, 2014). In Korea, all cattle carcasses should be evaluated by Korean carcass grading system. Established in 1992, the Korean carcass grading system presently has three levels of yield grade (YG) for meat amount (A, B, and C) and five levels of meat quality grade (QG) (1⁺⁺, 1⁺, 1, 2, and 3) (KAPE, 2016).

For beef quality grading in Japan, all cattle carcasses are graded at the 6th to 7th rib section at least one hour after ribbing. The following four items are independently eval-

uated: beef marbling; meat color and brightness; meat firmness and texture; and fat color, luster, and quality. Meat quality grade of the carcass is then assigned according to the lowest grade of these four items. Korean beef quality grading is also estimated based on several factors, including marbling score, meat color, fat color, firmness and texture of lean meat, and maturity of the exposed loin muscle at the 13th rib interface. The beef quality grading system is primarily determined by marbling score. It is additionally adjusted by other carcass traits. This means that marbling score is the most dominating determinant in Korea because Korean consumers have an extraordinary preference for high marbled meats.

In 1988, Wagyu marbling levels were assigned by the Beef Marbling Standard (BMS) using a plastic model made from silicone resin. This standard was calculated based on the circumference and area percentage of marbling particles in the rib eye section (*longissimus thoracis*). In October 2008, a new marbling standard using carcass photographs replaced the 1988 standard. In March 2014, an even newer marbling standard was implemented (Fig. 1). Graders now determine the BMS number (1 to 12) by comparing the actual carcass marbling to the standard

photograph of marbling. During this process, any larger inclusions of fat at the periphery of the rib eye are not considered as marbling according to the Japanese grading system.

The BMS of Korean carcass grading system has been changed by the addition of marbling number. In 1992, when the carcass grading system was established for the first time in Korea, the BMS had only 5 numbers (1 to 5) with 3 QG (1, 2, and 3). However, in 1997, new QG 1⁺ was added with new BMS No. 6 and No. 7 due to the appearance of improved marbling in Hanwoo beef. Furthermore, in 2004, another new QG 1⁺⁺ was added with new BMS No. 8 and No. 9 because of the emergence of highly marbled Hanwoo beef (Fig. 2). Nowadays, Hanwoo beef with QG 1⁺⁺ or 1⁺ is considered as a premium class of beef in Korea. Of Hanwoo cattle slaughtered in 2015, 10.0% were QG 1⁺⁺, 26.4% were QG 1⁺, and 31.4% were QG 1 (KAPE, 2016).

Marbling of Wagyu and Hanwoo Beef

The plentiful marbling of Wagyu and Hanwoo beef has attracted attention. In both Japan and Korea, the value of

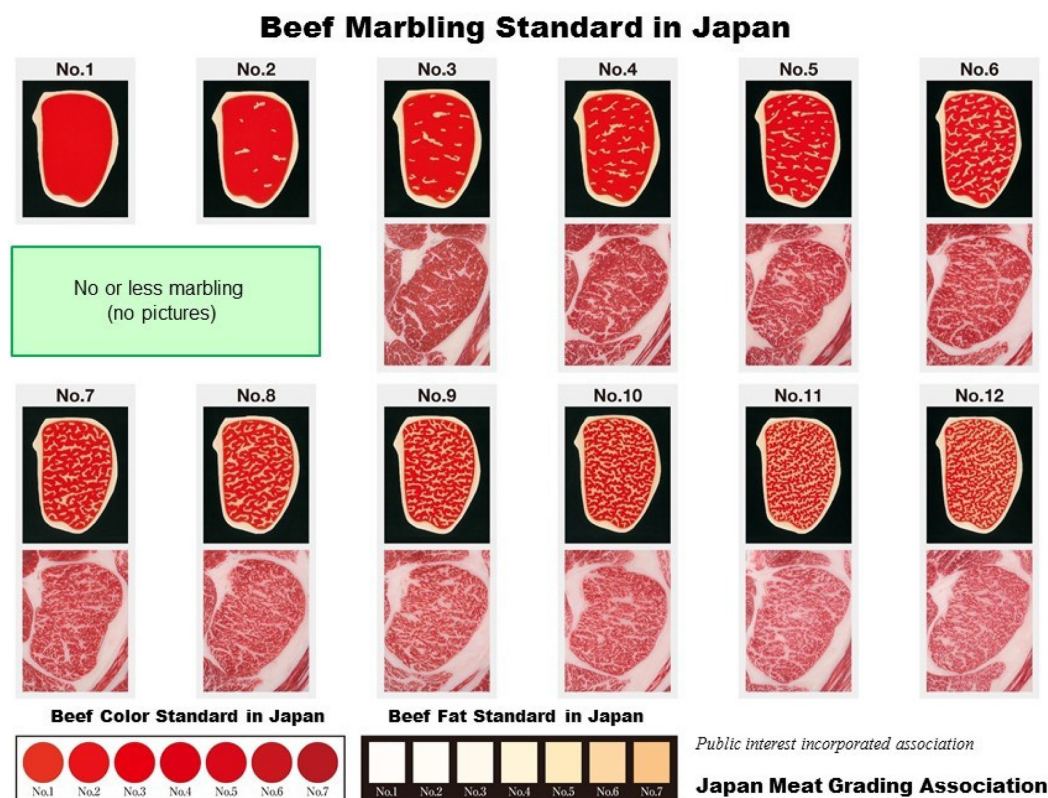


Fig. 1. Official picture standard of BMS (Beef Marbling Standard), BCS (Beef Color Standard) and BFS (Beef Fat Standard) by Japan Meat Grading Association (JMGA, 2014).

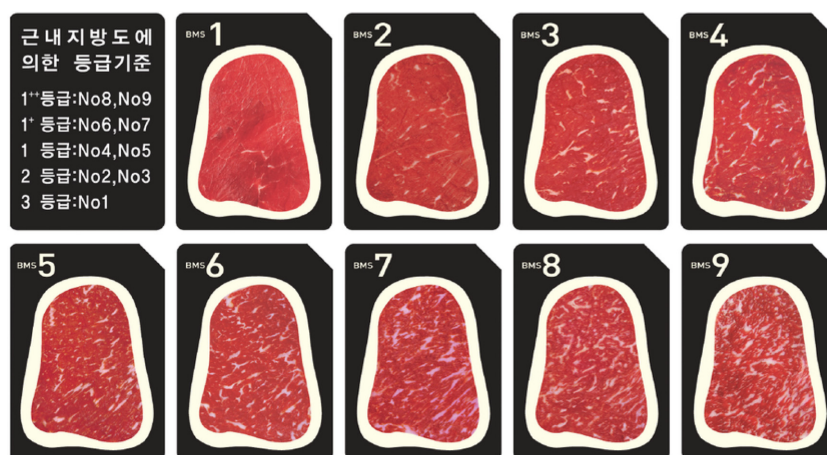


Fig. 2. Official picture standard of BMS (Beef Marbling Standard) used for the evaluation of quality grade of cattle carcass in Korea by Korean Institute for Animal Products Quality Evaluation (KAPE, 2015).

cattle carcasses is determined by a QG which considers marbling as a decisive determinant. Since the liberalization of beef importation, marbling has been greatly emphasized to differentiate domestic beef from imported beef (Hirooka, 2014; Hwang *et al.*, 2010). The high content of IMF can improve the texture and juiciness of Hanwoo beef and thereby its acceptability (Jung *et al.*, 2016). Korean consumers prefer QG 1⁺⁺ or 1⁺ beef because of its high IMF content (Kim *et al.*, 1999). Iida *et al.* (2015) have demonstrated that an increase in crude fat content (range 23.8–48.6%) can increase the tenderness, juiciness, and fattiness. However, they also reported that an increase in crude fat content can reduce the crude protein content and slightly reduce the content of umami components such as nucleic acid and glutamic acid.

It is well known that IMF content varies depending on feeding time, finishing diet, and breed type. To produce high QG beef, great attention has been paid to more accumulation of IMF in Wagyu and Hanwoo muscle. One of good strategy to increase IMF content in beef muscle is to extend slaughtering age. Although the marbling score is increased and reached a plateau at about 24 mon of age (Choi *et al.*, 2002), the slaughtering age of Hanwoo has been extended to increase the BMS score (Jo *et al.*, 2012). In Korea, the marketing age of Hanwoo has been extended to an average of 31 mon with weight of 719 kg to fatten the cattle (KAPE, 2015). Consequently, the marbling score has eventually increased. However, average daily gain is decreased due to increased slaughtering weight (Paek *et al.*, 1993). Recently, cattle in China are fed for unusually long periods of time before slaughter as Wagyu and Hanwoo. This might have contributed to their high IMF and

oleic acid contents (Smith, 2016; Tanaka, 1985).

It is clear that IMF increases with feeding time for grain-fed and pasture-fed cattle. However, the rate of IMF increase in grain-fed cattle is faster than that in pasture-fed cattle (Smith *et al.*, 2009). It has been reported that Wagyu fed on a high-concentration diet have higher expression of adipogenic transcription factors in the subcutaneous and intramuscular adipocytes than those fed on a high-roughage diet (Yamada and Nakanishi, 2012). The IMF content and the numbers of preadipocytes and adipocytes are reported to be higher in Wagyu than those in Angus (Duarte *et al.*, 2013). Gotoh *et al.* (2009) have reported that the IMF contents in the longissimus muscle of Wagyu, German Angus, Belgian Blue, and Holstein Friesian are 23.3%, 4.4%, 0.6%, and 4.7%, respectively. The Wagyu and European cattle breeds did not differ in their mechanisms of postnatal fat accretion. However, they differed in their efficiency of accretion of IMF (Gotoh *et al.*, 2009). For every 1% increase of IMF in the longissimus muscle, the increase amounts of subcutaneous adipose tissue in Wagyu, Holstein Friesian, German Angus, and Belgian Blue were 3.0, 4.3, 7.9, and 10.7 kg, respectively (Gotoh *et al.*, 2009).

Although IMF content is the most dominating determinant of beef quality, the IMF content is not the only parameter that decides the quality grade of beef carcass. Marbling is called “Shimo-furi” in Japanese and “Sang-gang” in Korean. It literally means “frosting”. In Japan, marbling with a fine appearance resembling frost is highly valued, but coarse marbling is not (Motoyama *et al.*, 2016). Recently, Korea also began to discriminate between fine and coarse marbling in Hanwoo beef. This marbling quality contributes to the tenderness of beef because IMF depo-

sits are found mainly between muscle fiber bundles, resulting in the disorganization of perimysium connective tissue (Nishimura, 2015; Sasaki *et al.*, 2012). Therefore, the sensory of tenderness could be qualitatively affected by histological difference in marbling due to difference in tissue disorganization extent.

Fatty Acid Composition of Wagyu and Hanwoo Beef

There are several types of fatty acids: 1) monounsaturated fatty acids (MUFA), 2) polyunsaturated fatty acids (PUFA), and 3) saturated fatty acid (SFA). PUFA such as linoleic acid, α -linolenic acid (n-3), γ -linolenic acid (n-6), Arachidonic acid, and so on contain many important compounds such as essential fatty acids. Beef is rich in SFA and MUFA. The fatty acid that has the highest amount in beef is oleic acid (C18:1n-9).

It has been reported that fatty acid compositions are different depending on breeds (Smith *et al.*, 2006; Zembayashi and Nishimura, 1996). The fatty acid compositions in highly marbled Wagyu and Hanwoo are considerably different from those in other cattle breeds. Highly marbled Wagyu beef has a higher percentage of MUFA within fat compared with other breeds (Yang *et al.*, 1999a). Smith *et al.* (2006) have investigated oleic acid concentrations in the subcutaneous adipose tissues of Wagyu, Hanwoo, Australian crossbred, Angus (corn-fed), Angus (hay-fed), and Angus (weaned) and found that they are 52.9%, 47.3%, 39.8%, 39.8%, 34.6%, and 32.9%, respectively. A higher percentage of MUFA will lead to a lower fat-melting point which contributes to the softness of beef fat and favorable beef flavor. It may decrease the circulating concentration of LDL cholesterol in consumers (Melton *et al.*, 1982; Rudel *et al.*, 1995; Smith, 1994). Therefore, fatty acid compositions of beef have recently become important in the beef industry, especially in highly marbled Wagyu and Hanwoo cattle.

Zembayashi *et al.* (1995) have investigated the effect of breed type (including Japanese Black) and sex on fatty acid compositions of subcutaneous and intramuscular lipids in finishing steers and heifers of pure Japanese Black and Holstein as well as crossbred Japanese Black, Holstein, Japanese Brown, and Charolais. They have reported that the Japanese Black is genetically predisposed to producing carcass lipids containing higher concentrations of MUFA than Holstein, Japanese Brown, or Charolais steers (Zembayashi *et al.*, 1995). Sturdivant *et al.* (1992) have also concluded that beef from purebred Wagyu cattle raised

Table 1. Comparison of intramuscular fatty acid compositions in longissimus muscle between Wagyu and Holstein steers fattened by an identical conventional fattening system (Data from Gotoh *et al.*, 2011)

Fatty acid	Wagyu (n=6)	Holstein (n=5)	p-value ¹⁾
IMF(%) ²⁾	32.066±2.805	17.34±2.864	<0.01
12:0	0.052±0.004	0.037±0.004	<0.05
14:0	2.840±0.172	2.726±0.282	n.s.
14:1	0.848±0.103	0.798±0.121	n.s.
15:0	0.402±0.037	0.351±0.039	n.s.
15:1	0.025±0.002	0.024±0.002	n.s.
16:0	26.144±0.546	28.009±0.661	0.055
16:1	4.069±0.225	3.833±0.162	n.s.
17:0	1.037±0.087	1.004±0.117	n.s.
17:1	0.986±0.082	0.825±0.114	n.s.
18:0	10.484±0.266	12.267±0.516	<0.05
18:1	50.040±0.911	47.465±0.980	n.s.
18:2 n-6	2.116±0.911	1.926±0.129	n.s.
18:3 n-3	0.121±0.036	0.175±0.062	n.s.
CLA 9c, 11t	0.302±0.031	0.260±0.015	n.s.
20:0	0.071±0.003	0.128±0.027	0.051
20:1	0.457±0.046	0.164±0.028	<0.001
ΣSFA ³⁾	41.033±0.562	44.524±0.842	<0.01
ΣMUFA ³⁾	56.472±0.704	53.112±0.853	<0.05
ΣPUFA ³⁾	2.539±0.225	2.363±0.094	n.s.

Values are expressed as mean (%)±S.E.

¹⁾Student's t-test. ²⁾IMF: intramuscular fat. ³⁾SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polysaturated fatty acids.

sed in Japan is rich in MUFA. Gotoh *et al.* (2011) have compared intramuscular fatty acid composition of longissimus muscle in 26-month-old Japanese Black steers and Holstein steers reared and fattened using a standard fattening system (Table 1). In the longissimus muscle of Japanese Black steers, a higher percentage of unsaturated fatty acid was found than that in Holstein steers (Gotoh *et al.*, 2014). Moreover, Gotoh *et al.* (2011) have also compared the IMF content and fatty acid compositions of 21 major skeletal muscles using the same animals. Muscles from the Japanese Black cattle contained a greater proportion of numerous fatty acids, particularly MUFA such as C16:1, C18:1, and C20:1 compared to fatty acids in Holstein cattle. In Japanese Black cattle, the proportion of SFA including C18:0 was much lower compared to that in Holstein cattle.

Cho *et al.* (2005) have investigated the fatty acid compositions of Hanwoo and Australian Angus beef and found a significant difference in fatty acid compositions between these two cattle breeds (Table 2). Especially, Angus beef had significantly higher n-3 PUFA while Hanwoo beef contained greater n-6 PUFA in three different muscles (Cho *et al.*, 2005). The difference in fatty acid composi-

Table 2. Comparison of fatty acid composition (% of total lipid) between Hanwoo and Angus *Longissimus* muscle (Data from Cho *et al.*, 2005)

Fatty acid	Australian Angus	Hanwoo	RSD ^a	Breed F statistic and significance
C14:0	2.56	3.00	0.35	78.24 ^{c***}
C16:0	29.79	28.21	1.85	97.30 ^{***}
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 ^b	46.51	40.20	2.27	486.32 ^{***}
USFA ^b	53.49	59.79	2.27	486.14 ^{***}
MUFA ^b	50.80	57.3	2.32	224.02 ^{***}
PUFA ^b	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 ^{***}

^aRSD: residual standard deviation. ^bSFA: saturated fatty acids, USFA: unsaturated fatty acids, MUFA: monosaturated fatty acids, PUFA: polysaturated fatty acids. ^cF-ratio statistic: * if $p < 0.05$, ** if $p < 0.01$, *** if $p < 0.001$.

tion might be attributed to the influence of different diets, forage, and grain feeding, although fatty acid profile in ruminants is not a direct reflection of the dietary fatty acid composition due to hydrogenation by rumen micro-organism (Enser *et al.*, 1998).

Therefore, it can be easily anticipated that Hanwoo beef has a fatty acid profile similar to that of high concentrated animals (Jo *et al.*, 2012). Recently, Hwang and Joo (2016) have evaluated the fatty acid profile of ten muscles from high marbled (QG 1⁺⁺) and low marbled (QG 2) Hanwoo carcass and found significant differences in fat content and fatty acid composition among 10 muscles and between high and low marbled Hanwoo beef. In particular, high marbled Hanwoo muscles had significantly higher proportion of MUFA due to higher oleic acid (C18:1) proportion, while low marbled Hanwoo muscles had higher proportion of SFA due to higher proportion of stearic acid (C18:0) (Hwang and Joo, 2016).

Stearoyl-CoA desaturase (SCD) was first identified and reported as one of the genes associated with beef fatty acid composition (Taniguchi *et al.*, 2004). This enzyme is res-

ponsible for converting SFA into MUFA in mammalian adipocytes. The composition of fatty acids stored in fat depots reflects the earlier action of SCD on substrates such as stearic acid and palmitic acid (Kim and Ntambi, 1999). Yang *et al.* (1999b) have reported interesting correlations between SCD enzyme activity and fatty acid composition in bovine adipose tissue. Although the adipogenic mechanism is extremely complicated, several genes have been identified and confirmed as either associated with or responsible for the fatty acid composition in Wagyu cattle (Gotoh *et al.*, 2014).

It is generally accepted that the concentration of oleic acid in beef adipose tissue is dependent on SCD expression and activity. Wagyu cattle are genetically disposed to produce more oleic acid (Smith *et al.*, 2006). Very high heritability has been reported for oleic acid in Wagyu cattle (Nogi *et al.*, 2011). Production conditions can also affect the concentration of oleic acid. Higher levels of concentrated feed in the later fattening period can lead to higher MUFA concentration in the subcutaneous adipose tissues of Wagyu steer (Kimura *et al.*, 1996).

Health Implications of Highly Marbled Wagyu and Hanwoo Beef

Interest in beef fat and fatty acids has been increasing, especially in highly marbled beef such as Wagyu and Hanwoo because fatty acids composition in the diet have impact on human health. Consumption of fat and cholesterol has been reported to be linked to cardiovascular disease, obesity, and cancer (Micha *et al.*, 2010; Pan *et al.*, 2012). Consequently, reduction of total fatty acid intake and replacement of SFA with PUFA have been recommended. However, not all SFA are linked to hyper-cholesterol or obesity. Ulbricht and Southgate (1991) have demonstrated that stearic acid has no effect on plasma cholesterol level and that oleic acid can lower serum cholesterol similar to PUFA. Furthermore, Pavan and Duckett (2013) have suggested that a higher proportion of oleic acid in beef is desirable because the consumption of high-oleic acid ground beef can increase HDL-cholesterol concentration (Gilmore *et al.*, 2011).

According to Smith (2016), the amount of fat consumed in a typical portion of beef will not increase risk factors for cardiovascular disease. Clinical trials have demonstrated that ground beef containing elevated oleic acid can increase the concentration of HDL-cholesterol or at least has no negative effect on the concentration of HDL-cholesterol. In earlier research on oleic acid, the major MUFA in beef, Grundy *et al.* (1988) have found that it can lower LDL-cholesterol without affecting beneficial HDL-cholesterol. Recently, Lahey *et al.* (2014) have reported that MUFA can normalize or improve lipid metabolism and maintain the balance in cardiac muscle. These have implied that MUFA have little effect on total cholesterol and that they are heart-healthy dietary fat that can lower LDL-cholesterol and increase HDL-cholesterol (Lahey *et al.*, 2014). This effect is repeatable when natural foods are used to supplement diets with oleic acid. In this regard, Smith (2016) have concluded that beef cattle should be raised under production conditions to increase the concentration of oleic acid in their edible tissue, i.e., by grain feeding over extended periods of time.

It is obvious that consumer in the world has an overwhelmingly negative attitude toward animal fats, especially saturated fat in meat for the last several decades (Ngapo and Dransfield, 2006; Williams and Droulez, 2010). According to Higgs (2000), the per capita decline in beef consumption in the US and other Western countries has been attributed in large part to animal fat phobia. Consumers have been warned to reduce saturated fat in

their diet and to avoid meat cuts containing high fat content. These health recommendations are obviously in conflict with the health of highly marbled Wagyu and Hanwoo beef. Many research studies have shown that the IMF of Wagyu and Hanwoo beef contains a lot of MUFA that could prevent arteriosclerosis. Researches have also demonstrated that high-oleic acid ground beef may reduce risk factors for cardiovascular disease (Adams *et al.*, 2010; Gilmore *et al.*, 2011; Gilmore *et al.*, 2013). Thus, although some consumers in Japan and Korea consider highly marbled Wagyu and Hanwoo beef as being unhealthy, there is no scientific evidence to indicate that beef that is high in oleic acid will increase risk factors for diseases (Smith, 2016).

Consequently, the role of animal fats in the diet should be re-evaluated because scientists around the globe increasingly doubt the validity of the so called “diet-heart hypothesis” (Barendse, 2014; Klurfeld, 2015; Ramsden *et al.*, 2016; Siri-Tarino *et al.*, 2010). It is now generally accepted that diets with low fat, high carbohydrate failed to curb obesity (Drewnowski, 2015). On the other hand, more recent functional medicine research studies have suggested that the intake of fat has positive effect on human health (Saito, 2016). It is essential to consume fats containing good quality fatty acids while reducing the consumption of food high in simple carbohydrates. Excessive intake of simple carbohydrates is detrimental to health because they have negative effects on the body (Yu *et al.*, 2013). In this regard, inclusion of high fat foods with superior sensory properties in a balanced diet such as highly marbled Wagyu and Hanwoo beef is likely to gain wider acceptance as a well-being food in the near future.

Conclusions

In Japan and Korea, highly marbled Wagyu and Hanwoo cattle are greatly prized for traditional meat cooking methods. Their marbling has been increased to meet domestic consumer preferences. Many researches have shown that Wagyu and Hanwoo cattle have high potential of accumulating IMF and producing highly marbled beef. The beef quality grading system in both countries is primarily determined by marbling score with BMS and additionally adjusted by other carcass traits. Literature suggests that IMF content varies on the basis of feeding time, finishing diet, and breed type. Great attention has been paid to more accumulation of IMF to produce high quality grade beef. It is clear that IMF increases with increased feeding time. The rate of IMF increase in grain-fed cattle is faster

than that in pasture-fed cattle. Literature also indicates that fatty acid composition varies between breeds. Highly marbled Wagyu and Hanwoo beef have higher proportions of MUFA due to higher concentrations of oleic acid. Many studies have shown that MUFAs have little effect on total cholesterol. They are heart-healthy dietary fat because they can lower LDL-cholesterol while increasing HDL-cholesterol. Clinical trials have also indicated that highly marbled beef does not increase LDL-cholesterol and that beef high in oleic acid can consistently increase HDL-cholesterol. Finally, literatures have concluded that high-oleic acid beef such as Wagyu and Hanwoo beef may reduce risk factors for cardiovascular diseases.

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