Meat Quality of Highly Marbled Imported Beef with Reference to Hanwoo Beef

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근내지방도가 높은 수입 등심육과 한우육의 육질특성 비교

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적 요

본 연구는 근내지방도가 높은 냉장 수입육과 한우 1등급 및 3등급육의 육질 비교를 위해 실시하였다. 쇠고기 전문점에서 화우(Wagyu) 4두, 엥거스(Angus) 4두, 한우 1등급 4두와 한우 3등급 3두의 등심육을 구입하여 시료로 이용하였다. 화우, 엥거스, 한우 1등급과 3등급의 근내지방 함량은 각각 22, 8, 13 및 4% 였고, 숙성기간은 31, 71, 14 및 14일 이였다. 한우 등급간 또는 수입육간에 육질 차이는 없었다. 수입육은 한우보다 유의적으로($P < 0.05$) 낮은 전단력을 보였다. 하지만 관능평가의 연도와 다즙성에는 위 내가지 육질사이에 차이점이 관찰되지 않았다. 한편, 한우가 향미에서 유의적으로($P < 0.05$) 높은 점수를 받아, 요리된 고기의 향이 더 우수한 것으로 평가되었다. 축종, 사양방법, 숙성일 차이 중 어떤 요인이 본 실험결과에 영향을 주었는가에 대한 의문이 남아있다. 하지만 이 결과는 높은 근내지방을 함유한 수입육 보다 한우고기가 더 우수한 관능 특성을 가졌다는 것을 단편적으로 보여주고 있다. 판별력 분석에서 수입육과 한우육을 분별하는 지방산은 C18 : 0, C18 : 1n-7, C18 : 1n-9, C20 : 3n-6, C20 : 4n-6 and n-3으로 나타났다. 하지만 수입육과 한우육에서 이 지방산들의 차이는 C18:0에서만 관찰되었다. 선별된 지방산들과 향미의 상호관계를 관찰하기 위해 주요인 분석을 실시한 결과 C18 : 0($P < 0.05$)와 C18 : 1n-7($P < 0.1$)가 향미와 음의 상관관계를 보였다. 본 연구의 결과는 한우고기가 더 높은 근내지방을 함유한 냉장 수입육보다 더 우수하다는 것을 시사하고, 낮은 양의 C18 : 0가 이와 관련된 후보 지방산이 될 수 있다는 것을 시사한다. 한우고기 차별화를 위해 본 결과가 축종, 사양방법 또는 도축 후 처리의 어떤 요인들과 관련되어 있는가에 대한 연구가 요구된다.

(**Key words** : Breed, Marbling, WB-shear force, Fatty acid, Sensory characteristics)

I INTRODUCTION

It has been shown that intramuscular fat improves eating quality upon 15% in its extractable level(Thompson, 2001), and explains approximately 10 ~ 15% of variations in palatability(Dikeman, 1987). However, underlying mechanisms by which the fat improve palatability have been controversial. Miller et al.(1994) postulated that intramuscular fat acts as lubricant in chewing action, and reduces the relative number of muscle fibers within a certain amount of meat. On the other hand, Rymill et al.(1997) demonstrated that intramuscular fat indirectly improved eating quality through its effect on the prevention of overcooking(e.g., burning), and raised a fundamental question whether the fat content is a direct cause of improved palatability in highly marbled meat. Similarly, Thompson(2001) believed that intramuscular fat increases consumer satisfaction by stim-

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ulating salivary gland, which consequently brings into being high juiciness in mouth feeling.

Our previous survey indicated that Korean consumer preferred highly marbled meat(Cho et al., 1999), and that was associated with more favorable palatability(Park et al., 2000). The latter study, using 229 Hanwoo *m. longissimus* with a large range of intramuscular fat content, demonstrated that meat containing high intramuscular fat received significantly higher sensory scores in tenderness, juiciness and flavor intensity. For the reason, Korean beef industry has made a long-term effort to improve the degree of marbling. On the other hand, highly marbled foreign product has been imported; while a total of imported beef took approximately 66% share in Korean beef market in 2003(Korean Ministry of Agriculture and Forest, 2003). Thus, the current study was conducted to evaluate objective and subjective meat quality traits for highly marbled imported beef *longissimus* muscle in comparison with Hanwoo beef.

Ⅱ MATERIALS AND METHODS

1. Sampling and treatment

A total of eight imported and seven Hanwoo *longissimus* muscles(visually from the 6th thoracic vertebrae to the last lumbar vertebrae) were purchased from HaNaRo Nong-Hyup Mart in Seoul. Breed, feeding regime and day of ageing were identified on the basis of labels on the whole cut box, as well as data from importing company. The imported products comprised four Wagyu (grain feeding for 450 days and aged for 31 days) and four Angus(grain feeding for 150 days and aged for 71 days). Seven Hanwoo samples were composed of four carcass quality grade (QG) 1 and three QG 3. As the domestic meat samples were collected following day of slaughter, the samples were aged at 1℃ for 14 days.

2. Quality determination

WB-shear force was measured on cooked steaks(2.54 cm thick) in a pre-heated water bath for 60 min until the core temperature reached 70℃ and then cooled in running water(ca. 18℃) for 30 min to reach a core temperature below 30℃. Eight cores of 1.27-cm diameter were made for each sample, and peak force was determined using a V-shaped shear blade with a cross-head speed of 400 mm/min(Wheeler et al., 2000). Cooking loss was calculated as percent of weight changes during cooking for WB-shear force measurement.

Non-trained eight panelists evaluated sensory characteristics of tenderness, juiciness and flavor intensity on a six-point scale. The panelists were asked to score from one (1) for extremely dislike to six for extremely like. Thin slice samples(ca. 4 mm in thickness, and 50 × 70 mm in size) were cooked by placing on the tin plate(ca. 245 ~ 255℃) with turning at the first pooling of liquid on the surface of the strip, or at the start of shrinkage. The cooked strip was immediately served to each panelist for evaluation. Intramuscular fat content was determined by a microwave-solvent extraction method described by AOAC (2000). Fatty acid composition was determined by the Folch solvent extraction method(Folch et al., 1957), according the method described by Chae et al.(2002).

3. Statistical evaluation

Least square means were estimated using a general liner model(SAS, 1997), and difference in objective and subjective meat quality traits between the four groups of meat were evaluated by a pair-different test at 0.05 %. Discriminant

analysis was conducted to classify difference in fatty acids between domestic and imported beef using a backward stepwise method with alpha to enter = 0.15(Systat, 2002). Principle component analysis was used to assess relationship between fatty acids and flavor intensity(Systat, 2002).

Ⅲ RESULTS AND DISCUSSION

1. Origin of products and meat quality characteristics

By definition, sensory characteristics of cooked meat is an overall mouth feel perceived by interactions between multi-parameters including deformation and breakdown of muscle fiber during a consecutive action of chewing, and stimulation of salivary gland(Jowitt, 1974). This can be explained by the so-called 'hole effect', by which the sensory panelists tended to perceive higher juiciness and flavor intensity with tender meat and, *vice versa* (Shorthose and Harris, 1991). For the reason, the effect of individual sensory trait such as tenderness, juiciness and flavor on consumer acceptability cannot be considered separately. In other words, toughness of fiber component, intramuscular fat content and water-holding capacity simultaneously influence overall eating quality and consumer satisfaction.

Given the facts, the current result cannot be a direct indication of meat quality associated with either breed or origin of products because ageing time considerably varied from 14 to 71 days (Table 1), but that mirrors its quality *per se* on the market. The current analysis showed that the imported Wagyu after 450 days of grain feeding had a 22% of intramuscular fat content in *longissimus* muscle(Table 1). Based on our unpublished data, that was a considerably higher percentage than that for average Hanwoo QG 1^{+}. On the other hand, the grain-fed Angus for 150 days had a significantly($P < 0.05$) lower intramuscular fat than Hanwoo QG 1, but greatly($P < 0.05$) higher than Hanwoo QG 3. This implies that the production strategy for highly marbled Hanwoo can be no longer sole solution for Korean beef industry. At the first glance, there was no difference in WB-shear force and sensory characteristics between Hanwoo QG 1 and 3, and between Wagyu and Angus. However, the imported products showed a significantly($P < 0.05$) lower WB-shear force than Hanwoo. This was likely

Table 1. Least square means and significant difference in objective and subjective meat quality traits between various carcass quality of domestic and imported beef

	Hanwoo beef		Imported beef		Av. SE[1)]
Carcass quality[2)]	QG 1	QG 3	Wagyu	Angus	
Day of ageing	14	14	31	71	
Intramuscular fat(%)	12.8[a]	4.4[b]	21.9[c]	7.9[d]	0.74
Shear force(kg)	4.1[a]	3.7[a]	2.4[b]	2.4[b]	0.41
Cooking loss(%)	19.6[a]	25.7[b]	20.2[a]	24.8[b]	0.19
Juiciness[3)]	4.5[a]	4.1[a]	4.6[a]	4.4[a]	0.28
Tenderness[3)]	4.8[a]	4.5[a]	5.3[a]	5.3[a]	0.31
Flavor intensity[3)]	4.9[a]	4.9[a]	4.0[b]	4.1[b]	0.22

[1)] Average standard error, numerous/denominator degree of freedom: 1/14.
[2)] QG 1 and QG 3: Carcass quality grade 1 and 3, respectively, Wagyu and Angus were fed in a grain feeding regime for 450 and 15 days, respectively.
[3)] 6: Extremely like, 1: Extremely dislike.

attributed to the considerably longer ageing period, and was rather anticipatable. It is general consensus that difference in meat toughness is largely equalized by approximately 14 days of chiller ageing(Hwang et al., 2003), and the changes take place at a relatively slower rate with extended ageing time(Lee and Lee, 1998). On the other hand, the instrument measurement was not reflected on sensory characteristics whereby sensory tenderness and juiciness did not differ between the domestic and foreign products.

Sole difference between Hanwoo and imported meats was observed in flavor intensity in that Hanwoo received significantly($P<0.05$) desirable scores. It has been shown that chiller ageing at 1℃ significantly increased 'off-odour' after approximately 35～60 days, depending on initial quality (Lee and Lee, 1998). However, it was unsure that the result was associated with differences in breed(Raes et al., 2003), feeding regime(Wood et al., 2003), ageing period(Lee and Lee, 1998), or interactions. Nevertheless, the result was an indication of superior eating quality of Hanwoo to the imported beef. An early study(Kim et al., 1999) showed that Hanwoo *longissimus* muscle was more acceptable than imported one when the Hanwoo meat contained significantly higher intramuscular fat. In addition to the study, the current result demonstrated that imported meat was less acceptable for Korean consumers, in spite of higher marbling than Hanwoo.

As Hanwoo QG 1 showed a significantly($P < 0.05$) less cooking loss than Hanwoo QG 3, more favorable sensory traits were somehow expected. However, difference was undetectable. Park et al.(2000) indicated that high intramuscular fat improved tenderness, juiciness and flavor when that was evaluated the following day after slaughter. The current result, on the other hand, indicated that the carcass quality grade had no detectable effect on sensory characteristics of longissimus muscle as well as objective texture measurement, when meats were aged for 14 days at 1℃.

2. Fatty acids related to flavor intensity

Apart from nutritional aspect, composition of fatty acids is a decisive component in meat quality due largely to their variations in melting points and oxidation capacity which have significant effects on palatability and flavor development during cooking(Wood et al., 2003). Numerous studies(e.g., Raes et al., 2003; Laborde et al., 2001) have demonstrated that fatty acid composition affected sensory characteristics. Since the Hanwoo and imported meats showed a significant difference only in flavor intensity, it was decided to identify fatty acids discriminating two products, and their correlations to flavor intensity. Firstly, 16 fatty acids, ratios of n3 / n6 and saturated fatty acids/unsaturated fatty acids were inputted to a discriminant analysis procedure to classify two groups of meats. Table 2 shows a linear function of discriminant analysis, group of means and correction rate. The analysis finally retained C18 : 0, C18 : 1n-7, C18 : 1n-9, C20 : 3n-6, C20 : 4n-6 and total n-3 polyunsaturated fatty acids(PUFA) by which imported beef and Hanwoo was differentiated at 100%.

Table 3 presents differences in the fatty acids between the meat quality groups, and their relations to tenderness, flavor and juiciness. Despite two groups of beef were clearly classified by the fatty acids, the significant difference in individual fatty acid between the groups varied. The result was rather expected as fatty acid compositions were significantly affected by breed, carcass quality, and chiller ageing, and these were in a similar trend with previous studies(Laborde et al., 2001; Insausti et al., 2004; Wood et al., 2003).

Table 2. Canonical discriminant functions of discriminant analysis, and canonical scores of group means and classification rate determined by a backward stepwise method with alpha to enter = 0.15

Variables	Coefficient	
Constant	0.624	
C18 : 0 (Stearic)	0.786	
C18 : 1n-7 (Vaccenic)	13.256	
C18 : 1n-9 (Oleic)	− 0.206	
C20 : 4n-6 (Dihomo-Ɣ-linolenic)	− 14.453	
C20 : 3n-6 (Arachidonic)	− 30.741	
Total n-3 PUFA	17.953	
Origin	Group means	Correction rate (%)
Hanwoo beef	− 4.55	100
Imported beef	3.982	100

Table 3. Least square means and significant difference in fatty acids between various carcass quality of domestic and imported beef, and simple correlation coefficient between fatty acid and sensory characteristics

	Hanwoo beef		Imported beef		Av. SE[1)]
Carcass quality[2)]	QG1	QG3	Wagyu	Angus	
C18 : 0(stearic)	11.5^{a}	13.7^{ab}	14.3^{bc}	16.2^{c}	0.66
C18 : 1n-7(vaccenic)	0.07^{a}	0.04^{a}	0.17^{a}	0.08^{a}	0.05
C18 : 1n-9(oleic)	42.3^{a}	46.7^{a}	47.2^{a}	44.1^{a}	3.95
C20 : 3n-6(Dihomo-Ɣ-linolenic)	0.18^{a}	0.11^{ab}	0.04^{b}	0.14^{a}	0.03
C20 : 4n-6(arachidonic)	0.31^{a}	0.46^{a}	0.16^{b}	0.32^{a}	0.05
Total n-3 PUFA	0.21^{a}	0.17^{a}	0.16^{a}	0.43^{b}	1.02

	Simple correlation coefficient (n=17)					
	C18 : 0	C18 : 1n-7	C18 : 1n-9	C20 : 3n-6	C20 : 4n-6	n3
Flavor intensity	− 0.59*	− 0.48†	− 0.03	0.21	0.31	− 0.30
Juiciness	− 0.12	− 0.35	0.36	− 0.38	− 0.61*	− 0.18
Tenderness	0.18	− 0.14	0.56*	− 0.53*	− 0.69*	0.10

1) Average standard error, numerous/denominator degree of freedom: 1/14.
2) QG 1 and QG 3: Carcass quality grade 1 and 3, respectively, Wagyu and Angus were fed in a grain feeding regime for 450 and 15 days, respectively.
^{abc} bearing the same letters within each row did not significantly differ (P>0.05).
†P < 0.1, *P < 0.05.

The current manuscript was not intended to discuss details about these effects on fatty acid composition. However, it was particularly noticeable that the level of total C18 : 0 for Hanwoo QG 1 was significantly(P < 0.05) lower than these for the foreign product. Even though sensory tenderness and juiciness did not differ between imported and Hanwoo beef, C20 : 4n-6 had a significant relationship with juiciness, while C18:1n-9, C20 : 3n-6 and C20 : 4n-6 were significantly(P < 0.05)

correlated with tenderness. In addition, flavor intensity was significantly correlated to C18 : 0($P < 0.05$) and C18 : 1n-7($P < 0.1$). The result indicated that fatty acids were associated with eating quality through their effects on various sensory characteristics.

To identify their correlations, the fatty acids and flavor intensity were reanalyzed using the principle component procedure(Fig. 1). Components 1 and 2 explained approximately 37 and 29% of variations, respectively, where component 1 differentiated C18 : 1n-9 versus C20 : 4n-6 and C40 : 3n-6. On the other hand, component 2 classified flavor intensity, as expected from simple correlation coefficients, with negative relations with C18 : 0 and C18 : 1n-7. Taken together, it appeared that the C18 series were involved in flavor intensity, and C18 : 0 could be a possible candidate for difference in flavor intensity between Hanwoo and imported meats.

Fig. 1. Plot of the first two principal component loading vectors using flavor (FLAVOR), C18 : 1n-9(C181N9), C18 : 0(C180), C18 : 1n-17(C181N17), C20 : 3n-6(C203N6), C20 : 4n-6(C204N6) and total n-3 PUFA(N3).

3. Implications

Chilled beef with a high degree of marbling has been imported, and currently takes a large share in beef market. This was somehow perturbing to Korean beef industry because highly marbled Hanwoo meat has been considered as a sturdy characteristic versus imported beef. The current study demonstrated that Korean consumers found more favorable flavor intensity in Hanwoo beef in spite of lower marbling score and higher WB-shear force. The result coincided with noticeable difference in C18 : 0. However, it was unsure that the difference was related with breed, feeding regime, or with ageing period. Further studies are required for breed specification in terms of sensory characteristics and consumer preference.

Ⅳ ABSTRACT

This study was conducted to assess objective and subjective meat quality traits for imported chilled beef with a high degree of marbling in *longissimus* muscle with reference to Hanwoo beef. Muscle samples of four Wagyu, four Angus, four Hanwoo grade 1, and three Hanwoo grade 3 were purchased from a commercial beef market. The meats had intramuscular fat content of approximately 22, 8, 13 and 4%, and aged for 31, 71, 14 and 14 days, respectively. Imported beef showed a significantly($P < 0.05$) lower WB-shear force than Hanwoo. However, the instrument measurement did not reflect sensory tenderness and juiciness, which were similar between the four groups. On the other hand, Hanwoo beef showed significantly($P < 0.05$) favorable flavor intensity. This was likely an indication of more a desirable eating quality for Hanwoo beef, regardless of the level of intramuscular fat content. Discriminant functions of C18 : 0, C18 : 1n-7, C18 : 1n-9, C20 : 3n-6, C20 : 4n-6 and total n-3 polyunsaturated fatty acids classified the domestic and foreign beef products at 100%, despite a noticeable difference between two groups existed only in C18 : 0. Principle component analysis indicated that

subjective flavor intensity was negatively related to C18 : 0 and C18 : 1n-7. The result indicated that C18 : 0 could be a possible candidate fatty acid for difference in flavor intensity between two beef groups. The current study demonstrated that the domestic product was more acceptable for Korean consumers. However, it was not identified whether the result was associated with breed, feeding regime, or ageing time. Further studies are required for breed specification in terms of sensory characteristics and consumer preference.

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