Fatty Acid Profiles and Sensory Properties of *Longissimus dorsi*, *Triceps brachii*, and *Semimembranosus* Muscles from Korean Hanwoo and Australian Angus Beef

S. H. Cho*, B. Y. Park, J. H. Kim, I. H. Hwang[1], J. H. Kim[2] and J. M. Lee
National Livestock Research Institute, Rural Development Administration, Suwon, 441-350, Korea

ABSTRACT : The study compared the fatty acid profiles of 3 muscles (Longissimus dorsi, LD, Triceps brachii, TB and Semimembranosus, SM) obtained from Korean Hanwoo (18 steers, 24 months old) and Australian Angus beef (18 steers, 24 months old) and assessed their role in sensory perception. The samples of each carcass were prepared in the same manner, and cooked both as traditional grilled steaks and Korean BBQ style. A total of 720 Korean sensory panelists evaluated the beef samples for tenderness, juiciness, flavor, and overall liking. Oleic acid (18:1) was significantly ($p<0.05$) higher in TB than that in LD and SM. The essential linoleic acid (C18:2) was significantly ($p<0.05$) higher in TB and SM than that in LD. For LD muscle, the proportion of saturated fatty acids was significantly ($p<0.05$) highest, while that of polyunsaturated fatty acids was lowest among the three muscles. Australian Angus beef had significantly ($p<0.05$) higher n-3 PUFA than that of the Korean Hanwoo for the three muscles, while the latter contained significantly ($p<0.05$) higher n-6 PUFA than that of the former. The clustering analysis showed that there a was significant difference in fatty acids such as C16:0, C16:1n7, C18:0, C18:2n6, C18:3n3, C20:3n6, C20:4n6, C22:4n6, and C22:5n3 for sensory perception (tenderness, juiciness, flavor and overall likeness) of the beef from two origins ($p<0.05$) among three clusters. Especially, C14:0 had a significant effect on sensory perception only for Korean Hanwoo beef, while C20:5n3 had a significant ($p<0.05$) effect only for Australian Angus beef based on clustering with the sensory variables. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 12 : 1786-1793)***

Key Words : Beef, Fatty Acid Profile, Sensory Traits, Consumer

INTRODUCTION

The consumer's decision to purchase beef is guided by the perception of a variety of sensory traits including color, tenderness, juiciness, and flavor. These traits are used by consumers as their bases on determining meat quality as well as healthiness (Verbeke and Viaene, 1999).

Variations in fatty acid composition explain some of the quality differences between muscles in shelf life and flavor (Wood et al., 2004). Flavor is an important characteristic of meat quality relating to the eating satisfaction that is perceived by the consumer. This is followed by appearance and tenderness (Love, 1994). Previous studies suggest that the fatty acid composition of ruminant meats can have an influence on meat flavor, along with other important quality attributes, and this is very much influenced by the diet given to the animal (Wood et al., 1999).

It has been reported that animals fed a high-grain diet had muscles containing higher concentrations of n-6 polyunsaturated fatty acids (PUFA), and produced a different flavor profile; while those fed grass diets had muscles with increased n-3 PUFA concentrations (Kemp et al., 1981; Larick and Turner, 1990). In grain-fed ruminants, the ratio C18:2/C18:3 is high compared with grass-fed animals (Wood et al., 1999) and is associated with meat flavor perception (Mitchell et al., 1991). In addition to diet, the effect of breed may be important. However, the effect of breed on flavor development is still debatable. It is often assumed by consumers that the traditional breeds, such as Aberdeen Angus, have better flavor than dairy breeds, such as Holstein-Friesian (Elmore et al., 2004). On the other hand, Boylston et al. (1996) reported that after cooking the meats of American and Japanese Wagyu, Angus, Longhorn, and US Choice breeds, there were no differences in the volatile profiles of the meats. The development of the aroma and flavor of cooked meat is a very complex process in which different components react to produce chemical intermediates or final flavor volatiles. In Korea, Hanwoo beef cattle are fattened indoors on high-concentrate diets. However, at the retail level, imported meat from more extensive grass-based production systems is made available. So far, no study has been performed to investigate the Korean consumers' perception on quality in relation to fatty acid composition of beef coming from different breeds and origins. This paper presents some results from a collaborative project between Australia and Korea, with the objectives comparing the fatty acid profiles of 3 muscles [*Longissimus dorsi* (LD), *Triceps brachii* (TB) and *Semimembranosus* (SM)] from Korean Hanwoo and Australian Angus beef, and assessing their role in the Korean consumers' sensory perception based on beef origin.

* Corresponding Author: Soohyun Cho. Tel: +82-31-290-1703, Fax: +82-31-290-1697, E-mail: shc0915@rda.go.kr
[1] Department of Animal Resources and Biotechnology, Chonbuk National University, Jeonju, 561-756, Korea.
[2] Department of Statistics, Duksung University, Korea.
Received December 8, 2004; Accepted July 25, 2005

MATERIALS AND METHODS

Animals, treatment and sample preparation

A total of 18 Korean Hanwoo steers and 18 Australian Angus steers were slaughtered in Korea and Australia, respectively. In Korea, 18 Hanwoo steers (~24 months of age; 150 days on a high concentrate ration before slaughter; 313-409 kg carcass weight) were obtained from a long-term feeding program at the RDA Institute, Suwon. Animals were slaughtered in three groups of six animals over a 3-day period. On each slaughter day, 6 animals were transported to the RDA abattoir, and fasted off feed for approximately 12 hours, with access to water prior to slaughter.

In Australia, 18 Angus steers (~24 months of age; 150 days on a high concentrate ration before slaughter; 342-423 kg carcass weight) were transported 1.5 h from the feedlot to a commercial abattoir at Bunbury WA, where animals were kept off feed, but with access to water overnight, before they were slaughtered. On the following day carcasses were deboned, and LD, SM and TB muscle were removed, vacuum packaged, and aged for 7 days at a 1°C chiller prior to cutting these into blocks for sensory evaluation and fatty acid analysis. After aging, fat and epimysium were removed from the muscles. The steaks (50×70×25 mm) were cut across the fiber direction prior to freezing at -20°C. To prepare Korean-style roasted beef strips, frozen meat blocks were tempered at 4°C and sliced into 20×75×4 mm (width×height×thickness) parallel to the fiber direction. The sensory samples were vacuum packaged separately, and stored at -20°C until analysis. Samples prepared in Australia were transported to Korea (NLRI, Suwon) in frozen state, and kept at -20°C until use.

pH and temperature

Chemical compositions were analyzed by using methods of the Association of Official Analytical Chemists (AOAC, 1996). Muscle temperature and pH were measured using for all cattle a portable needle-tipped combination electrode (NWK binar pH-K21, Germany) at approximately 15-min intervals in the center of the longissimus muscle between the 3rd and 4th lumbar vertebrae from approximately 30 min postmortem, until the muscle was judged to have reached ultimate pH. Another measurement was made the following day at approximately 24 h postmortem.

Sensory evaluation of Grill and Korean BBQ samples

The design comprised 18 Korean and 18 Australian carcasses ×3 muscles ×2 cooking techniques, which provided a total of 432 samples for sensory testing. Ten consumers evaluated each of the 432 samples, and each consumer assessed six diverse samples in a session. Consequently, a total of 720 consumers were involved in testing 4,320 samples ([432 samples×10 consumers per sample]/6 samples per consumer). The six samples for each consumer were allocated to session and serving order within a session using a latin square design. Consumers were recruited from government institutions and universities in the Suwon region. Socio-economic details were recorded for each consumer. For the testing sessions, venues were selected based on convenience to the consumer groups; the tests were conducted in an informal setting.

For the Korean BBQ style thin slice cooking, the BBQ strips were thawed to approximately 4°C. Individual strips were cooked by placing on the tin plate equipped with a water jacket (ca. 245-255°C). The strip was turned at the first pooling of liquid on the surface of the sample, or at the start of shrinkage. The cooked strips were immediately served to each panelist for evaluation. The sensory testing for Grill was performed according to the method described by Polkinghorne et al. (1999). Briefly, 10 thawed steaks (ca. 4°C) were grilled at 220-230°C by using a double surface Silex Griller for 5 min to achieve a medium degree of doneness (approximately 70°C). After cooking, the 10 steaks were rested for 2 min, and then sliced into halves prior to serving to 20 consumers.

At each session, every consumer was served a total of seven samples (the first was a common link used to familiarize consumers with the sensory protocol, followed by six experimental samples). Consumers were asked to score the samples for tenderness, juiciness, flavor, and overall liking. Scoring was done on a single sheet using four 100 mm line scale with 20 mm gradients marked. The four lines for sensory traits were anchored with the following words: tenderness = very tough (0) to very tender (100); juiciness = very dry (0) to very juicy (100); flavor = dislike extremely (0) to like extremely (100); overall liking = dislike extremely (0) to like extremely (100).

Fatty acid analysis

Total lipids of beef samples were extracted by using chloroform-methanol (2:1, v/v) according to the procedure of Folch et al. (1957). An aliquot of total lipid extract was methylated as described by Morrison and Smith (1964). Fatty acid methyl esters were analyzed by a gas chromatograph (Varian 3,600) fitted with a fused silica capillary column, omegawax 205 (30 m×0.32 mm ID, 0.25 μm film thickness). The injection port was at 250°C and the detector was maintained at 300°C. Results were expressed as percentages of the total fatty acid detected based on the total peak area.

Statistical analysis

The 10 consumer scores from each sample were averaged. The relationship least square means for fatty acids and the sensory characteristics were estimated by

Table 1. Means and variance for carcass traits for Australian Angus and Korean Hanwoo cattle (n = 18 carcasses for each treatment)

Carcass traits	Korean Hanwoo	Australian Angus
Carcass weight (kg)	371±38*	386±25
Fat depth (12/13th ribs mm)	8.8±3.1	15.7±4.8
Ossification score (USDA)	206±22	162±19
Marbling scores (USDA)	593.0±60	362.6±66
Intramuscular fat (%)	11.29±3.36	5.72±2.64
pH ultimate	5.46±0.07	5.45±0.03

* Mean±SD

using a linear model containing breed, and muscle cut as fixed effects. Models included fixed effects of breed, muscle, and their interactions. Each sensory characteristic and fatty acids were tested by using the ANOVA procedure. Fisher's least significance difference (LSD) was used for multiple comparison according to muscles. Linear correlation coefficients between variables were calculated.

For cluster analysis, 4 sensory characteristics were considered as grouping variables. Firstly, a hierarchical cluster analysis using Ward method was undertaken with the SAS CLUSTER procedure (SAS, 1996). The number of clusters to be retained was selected by considering the 'distance' between clusters and the profiles of the resulting tree graph. In this study, sensory properties were classified into 3 clusters for both the Korean Hanwoo and Australian Angus beef. Therefore each resulting cluster has significantly different sensory level.

Table 2. Comparison of fatty acid profiles for 3 muscles from Korean Hanwoo and Australian Angus beef

	TB*	LD	SM
C14:0	2.26^c	2.78^a	2.56^b
C16:0	24.28^c	29.00^a	27.15^b
C16:1(n7)	5.15^a	3.32^c	4.17^b
C18:0	8.98^c	11.58^a	10.23^b
C18:1(n9)	52.92^a	49.88^b	49.82^b
C18:1(n7)	1.34^a	0.54^c	0.99^b
C18:2(n6)	3.23^a	1.96^b	3.20^a
C18:3(n6)	0.02^a	0.003^b	0.007^b
C18:3(n3)	0.19^a	0.14^b	0.18^a
C20:1(n9)	0.28	0.28	0.30
C20:2(n6)	0.02^a	0.005^b	0.01^a
C20:3(n6)	0.26^a	0.13^b	0.28^a
C20:4(n6)	0.78^a	0.31^b	0.87^a
C20:5(n3)	0.08^a	0.03^c	0.06^b
C22:4(n6)	0.05^b	0.004^c	0.06^a
C22:5(n3)	0.15^a	0.04^c	0.10^b
SFA^d	35.52^c	43.36^a	39.94^b
USFA^d	64.48^a	56.64^c	60.06^b
MUFA^d	59.70^a	54.02^c	55.29^b
PUFA^d	4.78^a	2.62^b	4.78^a
n3	0.42^a	0.21^c	0.34^b
n6	4.36^a	2.41^b	4.44^a
MUFA:SFA	1.71^a	1.27^c	1.40^b
PUFA:SFA	0.14^a	0.06^c	0.13^b

$^{a-c}$ Means within a row having the same superscripts are not significantly different ($p>0.05$).

^{d} SFA: Saturated fatty acids; USFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.

* TB: *Triceps brachii*; LD: *Longissimus dorsi*; SM: *Semimembranosus* muscle.

RESULTS AND DISCUSSION

Carcass traits

The mean carcass traits and postmortem pH are shown in Table 1. There were wide ranges of USDA marbling score and intramuscular fat content, with 2.8 to 21% in LD. Although Elmore et al. (2004) reported that cereal-based diets, which are regarded as high-energy diets, lead to heavier and fatter animals than forage-based diets; which are regarded as low-energy diets, the carcass weight of Australian Angus and Korean Hanwoo used in this study were similar at the same age.

The Korean Hanwoo carcasses had lower subcutaneous fat depth, with higher ossification scores and marble scores (measured by USDA scoring systems) than those of the Australian carcasses. Korean carcasses had higher intramuscular fat contents (11.29%) than those of the Australian carcasses (5.72%). Marbling score, which was based on intramuscular fat content of LD muscle, was higher ($p<0.05$) in grain-fed cattle than that in grass-fed cattle.

Several researchers have observed higher marbling scores or lipid content of LD muscle for feedlot cattle than that of range cattle (Westerling and Hedrick, 1979; Miller et al., 1981). Previous workers have found that changes in fatty cid composition were related to fatness, age, carcass weight, and rate of fat deposition (Waldman et al., 1968; Huerta-Leidenz et al., 1996). May et al. (1993) compared the fatty acids profiles of Wagyu and purebred Angus steers and found a higher proportion of C16:1 and C18:1, and a lower proportion of C16:0 and C18:0 in the fat from Wagyu animals ($p<0.05$); although, it was not clear to the researchers if this difference was attributable solely to the breed difference, or in part, to fatness. Zembayashi et al. (1995) also found that Wagyu steers had proportions of C16:0, C16:1 and C18:1; different from those of the other sire breeds studied for the same degree of fatness. All carcasses reached normal ultimate pH, with an average of 5.45.

Fatty acid composition of different cut

For all muscles, fatty acids, ranked from the most important ones, were oleic acids (C18:1)<palmitic acids (C16:0)<stearic (C18:0) acids (Table 2). These, together with the non-negligible plamitoleic (C16:1n7), linoleic (C18:2n6) and myristic (C14:0) acids, added up to a total of about 95-98% fatty acid methyl esters. The three muscles differed significantly in the content of several fatty acids,

Table 3. Comparison of fatty acid concentrations (%) between 3 muscles within two breeds

Fatty acids	TB*		LD		SM		RSD[a]	Breed	Muscle	Breed ×muscle
	AusAng	KorHan	AusAng	KorHan	AusAng	KorHan				
C14:0	2.17[a]	2.35	2.56	3.00	2.61	2.53	0.35	78.24 [d]***	103.9***	26.37***
C16:0	24.25	24.31	29.79	28.21	28.19	26.10	1.85	37.30***	486.33***	17.72***
C16:1(n7)	5.04	5.27	2.70	3.94	3.88	4.46	1.37	88.19***	115.75***	6.72***
C18:0	10.09	7.87	14.16	9.00	11.87	8.58	0.89	2180.64**	644.37***	132.89***
C18:1(n9)	53.21	52.63	47.62	52.14	49.34	50.31	2.26	16.03***	188.34***	64.30***
C18:1(n7)	0.68	2.01	0.24	0.84	0.45	1.53	1.17	103.40***	18.52***	4.81**
C18:2(n6)	2.44	4.03	1.80	2.11	2.00	4.40	1.07	260.63***	62.06***	46.92***
C18:3(n6)	0.01	0.04	0.01	0.00	0.00	0.01	0.06	8.07**	4.47*	5.15**
C18:3(n3)	0.67	0.11	0.21	0.08	0.24	0.11	0.03	1576.1***	195.94***	13.33***
C20:1(n9)	0.13	0.34	0.24	0.32	0.25	0.36	0.12	55.49***	1.91	1.15
C20:2(n6)	0.01	0.01	0.00	0.01	0.01	0.02	0.02	29.51***	15.08***	3.53*
C20:3(n6)	0.27	0.24	0.15	0.11	0.21	0.34	0.11	3.51	95.76***	40.08***
C20:4(n6)	0.84	0.73	0.37	0.25	0.62	1.13	0.35	10.57*	125.71***	49.58***
C20:5(n3)	0.15	0.00	0.06	0.00	0.13	0.00	0.05	461.57***	99.03***	49.71***
C22:4(n6)	0.04	0.05	0.00	0.00	0.02	0.11	0.05	40.75***	45.17***	40.95***
C22:5(n3)	0.30	0.01	0.08	0.00	0.18	0.02	0.09	324.92***	128.06***	55.50***
SFA[b]	36.51	34.53	46.51	40.20	42.67	37.21	2.27	486.32***	577.04***	49.03***
USFA[b]	63.49	65.47	53.49	59.79	57.33	62.79	2.27	486.14***	777.97***	48.95***
MUFA[b]	59.15	60.25	50.80	57.23	53.92	56.65	2.32	224.02***	460.87***	66.91***
PUFA[b]	4.33	5.23	2.69	2.56	3.41	6.14	1.51	102.72***	108.81***	44.28***
n3	0.71	0.11	0.35	0.08	0.55	0.13	0.15	637.65***	158.32***	53.18***
n6	3.61	5.10	2.34	2.48	2.86	6.01	1.43	178.91***	93.70***	52.74***
n6:n3	5.35	43.74	7.60	30.79	6.06	46.81	8.56	1695.1***	14.27***	63.00***
MUFA:SFA	1.63	1.77	1.10	1.44	1.27	1.53	0.15	321.69***	585.76***	22.50***
PUFA:SFA	0.12	0.16	0.16	0.06	0.08	0.17	0.04	153.69***	158.42***	43.97***
DF[c]								1	2	2

* TB: *Triceps brachii*; LD: *Longissimus dorsi*; SM: *Semimembranosus* muscle.

[a] AusAng: Australian Angus; KorHan, Korean Hanwoo. [b] RSD: residual standard deviation.

[c] SFA: Saturated fatty acids; USFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.

[d] DF: Degree of freedom. [e] F-ratio statistic. * if $p<0.05$. ** if $p<0.01$. *** if $p<0.001$.

especially, SFA, C18:0. These results are consisted with those of the previous research (Badiani et al., 2002). Oleic acid (18:1) was significantly higher ($p<0.05$) in TB than that in LD and SM when fatty acids were pooled by both breeds. Likewise, the linoleic acid (C18:2), an essential fatty acid, was significantly higher in TB and SM than that in LD ($p<0.05$). Proportions of other essential fatty acids, linolenic (C18:3) and arachidonic (C20:4), were not significantly different between TB and SM. For TB, the proportion of saturated fatty acids was significantly lower, while that of the unsaturated fatty acids was significantly higher than that of other muscles. TB had a higher proportion of n-3 and n-6 polyunsaturated fatty acids than LD for both breeds. For LD, the proportion of saturated fatty acids was highest, while that of the unsaturated fatty acids was lowest among the three muscles. LD muscle had lower percentages of polyunsaturated fatty acids than those of the other muscles. As for sensory evaluation results, the contents of C14:0, C16:0, and C18:0 were significantly higher in LD, and it has been reported that LD was the highly preferred portion by the Korean consumers when they compared this with other muscles cooked under two cooking methods (Hwang et al., 2004). This confirmed the correlation between saturated fatty acids and sensory results.

Comparison of fatty acid composition of 3 muscles by breed

Fatty acid profiles indicated some significant differences according to different breeds, muscle types, and their interactions, and they differed between two breeds based on the analysis of the three muscles (Table 3). Hanwoo beef from cattle raised on long-term concentrate feeding had higher C16:1n7, C18:1n7, C18:2n6 and C20:1n9 than Angus beef, while those Angus animals raised on grass feeding had beef which contained higher C18:0, C18:3n3, C20:4n6, C20:5n3 and C22:5n3 than the analogues. Australian Angus beef had significantly higher n-3 PUFA, whereas Korean Hanwoo beef contained higher n-6 PUFA for the three muscles being studied. The proportion of saturated fatty acids was significantly higher in Angus beef, and that of the unsaturated fatty acids was significantly higher in Hanwoo beef. The contents of C16:0 and C18:0 were higher in Angus beef for all three muscles, while C14:0 was higher in Hanwoo beef for TB and LD muscles than in Angus beef, respectively (Table 3).

Fatty acid compositions between two breeds are

Table 4. Correlation coefficients between fatty acids and sensory properties

	Tenderness	Juiciness	Flavor	Overall likeness
SFA[a]	0.294**	0.154**	0.237**	0.268
USFA[a]	-0.294**	-0.154**	-0.237**	-0.268**
MUFA[a]	-0.183**	-0.046	-0.178**	-0.161**
PUFA[a]	-0.336**	-0.282**	-0.205**	-0.318**
n3	-0.042	-0.090*	0.017	-0.027
n6	-0.338**	-0.274**	-0.213**	-0.322**
n6:n3	-0.236**	-0.138**	-0.192**	-0.230**
MUFA:SFA	-0.242**	-0.099*	-0.209**	-0.218**
PUFA:SFA	-0.342**	-0.261**	-0.217**	-0.321**

[a] SFA: Saturated fatty acids; USFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.
* if $p<0.05$, ** if $p<0.01$.

possibly attributable to the influence of different diets such as forage and concentrate (grain) feeding on meat lipid composition in two countries. Based on the literature (Miller et al., 1981; Melton et al., 1982; Sinclair and O'Dea, 1987; Duckett et al., 1993), it is evident that the sample cuts in this study had both characters of meat from concentrate-fed cattle (lower contents of C18:0 and C18:3n3, higher content of C18:1n7) and certain valuable features of meat from forage-fed cattle (particularly lower contents of C18:2n6 and C20:4n6), possibly because, the latter kind of meat had a rather low fat content (Badiani et al., 2002). Ruminant meats had a more favorable n-6: n-3 ratio, due to lesser C18: 2 than those in pork; and relatively higher levels of n-3 PUFA, especially, C18:3 (Wood et al., 2004). Angus beef had significantly lower n6: n3 ratio than Hanwoo beef due to its high contents of n-3 PUFA (C18:3n3, C20:5n3, C22:5n3) and lower contents of n-6 PUFA (C18:2n6, C18:3n6 and C22:4n6).

Although, the fatty acid profile in ruminants is not a direct reflection of the dietary fatty acid composition due to hydrogenation by rumen micro-organisms, some changes in this profile can be attributed to the diet. Grass-fed cattle have much higher concentrations of *n*-3 polyunsaturated fatty acids (PUFA) (Marmer et al., 1984; Enser et al., 1998) and total monounsaturated fatty acids (MUFA) (Miller et al., 1967; Lantham et al., 1972; Marmer et al., 1984) than concentrate-fed animals, which in turn have higher concentrations of *n*-6 PUFA. The percentage of linolenic acid (C18:3) is also higher in the forage-fed animals (Marmer et al., 1984; Duckett et al., 1993; Patil et al., 1993; Enser et al., 1998) than in that of concentrate-fed animals.

Kook et al. (2002) reported that concentrate diet supplemented with fish oil at 5% of the diet significantly increased concentrations of n-3 fatty acids. Through many studies, researchers have established that beef from cattle raised exclusively on pasture has lesser desirable flavor than that of beef from cattle fed grain supplements or finished on grain. A variety of flavor notes have been used to describe the undesirable flavor, e.g. grassy, intense milky-oily, sour, and fishy (Brown et al., 1979; Melton et al., 1982; Larick et al., 1987). The causes for this undesirable flavor of forage-fed beef are still not completely understood; although, researchers have attributed these to variations in muscle fatty acid composition (Brown et al., 1979; Westerling and Hedrick, 1979; Melton et al., 1982), level and type of phospholipid (Larick and Turner, 1990), and differences in volatile content (Larick et al., 1987; Maruri and Larick, 1992).

Fatty acid profiles and sensory properties

The saturated fatty acids such as C16:0 and C18:0 were positively correlated with all sensory traits, while the unsaturated fatty acids such as C16:1n7, C18:2n6, C20:2n6, C20:3n6, C20:4n6, and C22:4n6 were negatively correlated with all sensory traits ($p<0.05$) (Table 4). In particular, the polyunsaturated fatty acids had significant negative correlation with tenderness, flavor, juiciness, and overall likeness. In this study, overall likeness had significantly negative correlation with C16:1n7, C18:1n7, C18:3n6, C20:1n9, C20:2n6, and C22:4n6; although, the simple correlation coefficients were low (r values of less than 0.35). The positive relationship between 18:3 and meat flavor is that the oxidation product of 18:3 and its derivative is directly responsible for the difference in flavor that was observed between grass-fed cattle and sheep (Wood et al., 2004). It is generally accepted that an increased level of the intramuscular fat (IMF) has a positive influence on the sensory qualities (Fernandez et al., 1999). As C18:1 is the main fatty acid in the intramuscular fat in cattle and sheep, it has been positively correlated with cooked beef fat flavor (Larick and Turner, 1990). Dryden and Marchello (1970) reported that the muscle *Longissimus dorsi* with high percentages of oleate generally scored higher in taste panel evaluations. Hanwoo beef contained significantly higher contents of C18:1n7 for three muscles with their relatively high level of marbling than Angus beef in this experiment. Total contents of n-3 fatty acids were not significantly correlated with sensory properties, except for juiciness; while total contents of n-6 had significantly negative correlations with all factors of sensory properties (tenderness, juiciness, like flavor and overall likeness) in this study.

Clustering analysis was used for the consumers with similar preference ranges in beef evaluation (Table 5). The coordinates of each beef origin obtained in the 4 dimensions of the sensory characteristic were used as clustering variables. It should be noted that some saturated fatty acids (C16:0, C18:0) and unsaturated fatty acids (C16:1n7, C18:2n6, C18:3n3, C20:3n6, C20:4n6, C22:4n6, C22:5n3)

Table 5. Cluster Means of sensory characteristics (tenderness, juiciness, like-flavor, overall likeness) and ANOVA results of comparing cluster means of fatty acids

Cluster	Australian Angus beef			Korean Hanwoo beef		
	1	2	3	1	2	3
Tenderness**	74.33[b]±6.10	59.38±4.68	44.96±7.21	73.77±6.64	59.61±4.95	42.72±8.40
Juiciness**	68.41±7.96	59.02±6.17	53.96±6.85	69.36±5.55	60.14±7.34	54.06±7.76
Flavor**	67.02±6.60	61.84±4.43	54.82±5.73	64.76±4.60	60.70±4.73	54.74±5.56
Overall likeness**	70.41±5.65	60.65±4.16	49.33±5.47	70.56±4.80	60.40±3.92	48.02±6.78
Fatty acids		F-ratio[c]			F-ratio	
C14:0		1.26			9.75**	
C16:0		8.60**			6.52**	
C16:1(n7)		4.28*			4.30*	
C18:0		8.94**			7.01**	
C18:1(n9)		4.55			0.09	
C18:1(n7)		0.25			0.47	
C18:2(n6)		4.82**			10.54**	
C18:3(n6)		1.44			1.57	
C18:3(n3)		6.10***			11.81**	
C20:1(n9)		2.03			2.22	
C20:2(n6)		1.66			2.83	
C20:3(n6)		14.14**			12.64**	
C20:4(n6)		17.18**			16.86**	
C20:5(n3)		15.44**			0.01	
C22:4(n6)		8.85**			7.88**	
C22:5(n3)		17.42**			3.65*	
SFA[a]		11.04**			10.21**	
USFA[a]		11.04**			10.22**	
MUFA[a]		6.19**			1.13	
PUFA[a]		12.28**			13.70**	
n3		17.16**			9.63**	
n6		10.08**			13.60**	
n6:n3		3.65*			6.06**	
MUFA:SFA		7.41**			5.77**	
PUFA:SFA		13.33**			14.41**	

[a] SFA: Saturated fatty acids; USFA: Unsaturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.
[b] Means±standard deviation: Scores were based on 100 mm line scale (tenderness; 0 = very tough 100 = very tender, juiciness; 0 = very dry 100 = very juicy; flavor; 0 = dislike extremely 100 = like extremely; overall liking: 0 = dislike extremely 100 = like extremely).
[c] F-ratio: F-ratio statistic for one way ANOVA and * if $p<0.05$, ** if $p<0.01$, *** if $p<0.001$.

affected the Korean consumers' preference clustering for Australian angus beef as well as for Korean Hanwoo beef. However, there were two fatty acids found to affect differently on the preference clustering depending on beef origin. For example, C14:0 was significantly different in 3 clusters based on the Korean consumers' sensory variables evaluated on Hanwoo beef; while C20:5n3 was significantly different in 3 clusters based on the Korean consumers' sensory variables evaluated on Australian angus beef. C14:0 might affect the taste of Hanwoo beef and C20:5n3 might affect the taste of Australian angus beef in the Korean consumers.

CONCLUSIONS

The fatty acid compositions were significantly different between from the two beef origins, but the reason for this difference, whether emanating from breed or diet, was not clear in this study. Although there were some specific fatty acids related with the sensory perception of Korean consumers for both beef origin, effects of C14:0 and C20:5n3 on the taste were different depending on beef origin in three clusters. The results of this study will help meat industries or processors to better understand the Korean consumers.

ACKNOWLEDGMENTS

Meat Standard Australia and NLRI, Korea are thanked for their financial support. Staff from Sensory Solution and NLRI are also thanked for their dedication to sensory evaluation.

REFERENCES

AOAC. 1996. Official Methods of Analysiss.Washington DC.

Badiani, A., S. Stipa, F. Bitossi, P. P. Gatta, G. Vignola and R. Chizzolini. 2002. Lipid composition, retention and oxidation in fresh and completely trimmed beef muscles as affected by common culinary practices. Meat Sci. 60:169-186.

Boylston, T. D., S. A. Morgan, K. A. Johnsen, R. W. Jr. Wright, J. R. busboom and J. J. Reeves. 1996. Volatile lipid oxidation products of Wagyu and domestic breeds of beef. J. Agric. Food Chem. 44:1091-1095.

Brown, H. G., S. L. Melton, M. J. Riemann and W. R. Backus. 1979. Effects of energy intake and feed source on chemical changes and flavor of ground beef during frozen storage. J. Anim. Sci. 48:338-347.

Duckett, S. K., D. G. Wagner, L. D. Yates, H. G. Dolezal and S. G. May. 1993 Effects of time on feed on beef nutrient composition. J. Anim. Sci. 71:2079-2088.

Dryden, F. D. and J. A. Marchello. 1970. Influence of total lipid and fatty acid composition upon the palatability of three bovine muscles. J. Anim. Sci. 31:36.

Elmore, J. S., H. E. Warren, D. S. Mottram, N. D. Scollan, M. Enser, R. I. Richardson and J. D. Wood. 2004. A comparison of the aroma volatiles and fatty acid compositions of grilled beef muscle from Aberdeen Angus and Holstein-Friesian steers fed diets based on silage or concentrates Meat Sci. 68:27-33

Enser, M., K. G. Hallett, B. Hewett, G. A. J. Fursey, J. D. Wood, and G. Harrington. 1998. Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. Meat Sci. 49:329-

Fernandez, X., G. Monin, A. Talmamt, J. Mourot and B. Lebret. 1999. Influence of intramuscular fat content on the quality of pig meat-2. Consumer acceptability of m. longissimus lumborum. Meat Sci. 53:67-72.

Folch, J., M. Lees and G. H. S. Stanley. 1957. A simple method for the isolation and purification of lipids from animal tissues. J. Biol. Chem. 226:497-500.

Huerta-Leidenz, N. O., H. R. Cross, J. W. Savell, D. K. Lunt, J. F. Baker and S. B. Smith. 1996. Fatty acid composition of subcutaneous adipose tissue from male calves at different stages of growth. J. Anim. Sci. 74:1256.

Hwang, I. H., B. Y. Park, S. H. Cho, J. H. Kim and J. M. Lee. 2004. Meat quality of highly marbled imported beef with reference to Hanwoo beef. Kor. J. Anim. Sci. Technol. 46:659-666.

Kemp, J. D., L. Mahyuddin, D. J. Ely, J. D. Fox and W. G. Moody. 1981. Effect of feeding systems, slaughter weight and sex on organoleptic properties and fatty acid composition of lamb. J. Anim. Sci. 51:321-330.

Kook, K., B. H. Choi, S. S. Sun, F. Garcia and K. H. Myung. 2002. Effect of fish oil supplement on growth performance, ruminal metabolism and fatty acid composition of Longissimus muscle in Korean cattle. Asian-Aust. J. Anim. Sci. 15:66-71.

Lantham, M. J., J. E. Storry and M. E. Sharpe. 1972. Effect of low roughage diets on the microflora and lipid metabolism in the rumen. Appl. Microbiol. 24:871.

Larick, D. K. and B. E. Turner. 1990. Head space volatiles and sensory characteristics of ground beef from forage- and grain fed heifers. J. Food Sci. 54:649-654.

Larick, D. K., H. B. Hedrick, M. E. Bailey, J. E. Williams, D. L. Hancoock, G. B. Garner and R. E. Morrow. 1987. Flavor constituents of beef as influenced by forage, and grain feeding. J. Food Sci. 52:245-251.

Love, J. 1994. Product acceptability evaluation. In. (Ed. A. M. Pearson and T. R. Dutson). Quality attributes and their measurement in meat, poultry and fish products (pp. 337-358). Glasgow: Blackie Academic & Professional.

Marmer, W. N., R. J. Maxwell and J. E. Wiliams. 1984. Effects of dietary regimen and tissue site on bovine fatty acid profiles. J. Anim. Sci. 59:109-121.

Maruri, J. L. and D. K. Larick. 1992. Volatile concentration and flavor of beef as influenced by diet. J. Food Sci. 57:1275-1281.

May, S. G., C. A. Sturdivant, D. K. Lunt, R. K. Miller and S. B. Smith. 1993. Comparison of sensory characteristics and fatty acid composition between Wagyu crossbred and Angus steers. Meat Sci. 35:289.

Melton, S. L., M. Amiri, G. W. Davis and W. R. Backus. 1982. Flavor and chemical characteristics of ground beef from grass-, forage-grain- and grain finished steers. J. Anim. Sci. 55:77-87.

Miller, G. J., T. R. Varnell and R. W. Rice. 1967. Fatty acid composition of certain ovine tissues as affected by maintenance level rations of roughage and concentrate. J. Anim. Sci. 29:41-45.

Miller, G. J., M. L. Masor and M. L. Riley. 1981. Intramuscular lipids and triglyceride structures in range and feedlot steers. J. Food Sci. 46:1333-1335.

Mitchell, G. E., A. W. Reed and S. A. Rogers. 1991. Influence of feeding regimen on the sensory qualitys and fatty acid contents of beef steaks. J. Food Sci. 56:1101-1103.

Morrison, W. R. and L. M. Smith. 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron trifluoride-methanol. J. Lipid Res. 5:600-608.

Patil, A. R., A. L. Goetsch, P. K. Jr. Lewis and C. E. Heird. 1993. Effects of supplementing growing steers with high levels of partially higrogentd tallow on feed intake, digestibility, live weight gain and carcass characteristics. J. Anim. Sci. 71:2284-2292.

Polkinghorne, R., R. Wastson, M. Porter, A. Gee, J. Scott and J. Thompson. 1999. Meat Standards Australia, A 'PACCP' based beef grading scheme for consumers. 1) The use of consumer scores to set grade standards. In *Proceedings 45th international congress of meat science and technology* (pp. 14-15), 1-6 August 1999, Yokohama, Japan.

SAS. 1996. SAS STAT User's Guide. Statistics. Cary NC.

Sinclair, A. J. and K. O'Dea. 1987. The lipid levels and fatty acid composition of the lean portions of Australian beef and lamb. Food Technol. Australia, 39:228-231.

Verbeke, W. and J. Viaene. 1999. Beliefs, attitude and behaviour towards fresh meat consumption in Belgium: empirical evidence from a consumer survey. Food Quality and Preference, 10:437-445.

Waldman, R. C., G. G. Suess and V. H. Brungardt. 1968. Fatty acids of certain bovine tissue and their association with growth carcass and palatability traits. J. Anim. Sci. 27:632.

Westerling, D. B. and H. B. Hedrick. 1979. Fatty acid composition of bovine lipids as influenced by diet, sex and anatomical location and relationship to sensory characteristics. J. Anim. Sci. 48:1343-1348.

Wood, J. D., M. Enser, A. V. Fisher, G. R. Nute, R. I. Richardson and P. R. Sheard. 1999. Manipulating meat quality and composition. Proc. Nutr. Soc. 58:1-8.

Wood, J. D., R. I. Richardson, G. R. Nute, A. V. Fisher, M. M. Campo, E. K. Kasapidou, P. R. Sheard and M. Enser. 2003. Effects of fatty acids on meat quality; a review. Meat Sci. 66:21-32.

Wood, J. D., G. R. Nute, R. I. Richardson, F. M. Whittington, O. Southwood, G. Plastow, R. Mansbridge, N. da Costa and K. C. Chang. 2004. Effects of breed, diet and muscle on fat deposition and eating quality in pigs. Meat Sci. 67:651-667.

Zembayashi, M., K. Nishimura, D. K. Lunt and S. B. Smith. 1995. Effect of breed type and sex on the fatty acid composition of subcutaneous and intramuscular lipids of finishing steers and heifers. J. Anim. Sci. 73:3325.