Food Sci. Biotechnol. Vol. 17, No. 3, pp. 495 ~ 500 (2008)

Food Science and Biotechnology

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Effect of Fatty Acid Profiles on Sensory Properties of Beef Evaluated by Korean and Australian Consumer Groups

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Abstract This study assessed the role of fatty acids on beef preference of 2 consumer groups from South Korea and Australia. Three muscles (*longissimus dorsi, triceps brachii,* and *semimembranosus*) were obtained from 36 carcasses (18 Hanwoo steers and 18 Angus steers) and the cooked beef samples were evaluated by 1,080 consumers (720 Korean consumer panels and 360 Australian consumer panels). The cluster analysis showed that the Korean consumers had more significant relationship with fatty acid composition of beef than that of the Australian consumers when evaluated Australian Angus beef. Only C20:5(*n*-3), and C22:5(*n*-3) affected preference clustering for Australian consumers; while saturated (C16:0 and C18:0) as well as unsaturated fatty acids [C16:1(*n*-7), C18:2(*n*-6), C18:3(*n*-3), C20:3(*n*-6), C20:4(*n*-6), C20:5(*n*-3), C22:4(*n*-6), C22:5(*n*-3)] affected preference clustering for Korean consumers ($p<0.05$). In the discriminant analysis of Korean consumer's preference clustering, C20:5(*n*-3) was a significant fatty acid for Australian Angus beef while the C20:4(*n*-6) and C18:0 for Korean Hanwoo beef to evaluate the palatability ($p<0.05$). Therefore, fatty acid compositions impact Korean consumer's preference of beef.

Keywords: beef, palatability, fatty acid, consumer group

Introduction

Meat and beef consumption per capita in Korea increased by approximately 21.3 and 11.4% to 31.3 and 6.8 kg/year from 1994 to 2004 (1). Following the World Trade Organization (WTO) agreements, Korea began to import beef from several countries in 2001 and became the 4th highest importer as such volume of 250 MT per year (2).

Based on the previous research, Korean consumers preferred Hanwoo beef since it has high intramuscular fat contents (3). Although the Waygu is considered as high marbled beef, Hwang *et al.* (4) reported that it is less acceptable than Hanwoo beef. In contrast to the Korean consumers, Australian consumers were generally known to prefer lean beef and intramuscular fat did not affect the sensory palatability of beef (5). A series of studies done on the effect of cooking methods to consumers preference implied that consumers' satisfaction largely depended on how the meat was cooked and the composition of the taste panel (6-8).

The fatty acid composition of beef is known to influence not only the nutritional and storage stability, but also the sensory qualities of both fresh and processed meat products. The amount and proportions of fatty acids in the main lipid fraction of the muscle such as neutral lipid and phospholipids differ, and variations in the proportions of fatty acids within these components explain some of the quality differences between muscles in shelf life and flavor (9). In addition, sensory quality of beef can be affected by internal and external factors which vary between countries.

At present, no study has yet been undertaken to evaluate the palatability of beef in relation to its fatty acid composition between consumers in different countries. This study is part of the Australia-Korea collaborative project which hopes to investigate the effect of fatty acid composition to sensory qualities of beef such as flavor and over-all preference from the point of view of Korean and Australian consumer groups. The consumers evaluated the beef cooked as the traditionally grilled steaks and thin-sliced/roasted beef.

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 (ca. 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 National Institute of Animal Science (NIAS), Suwon, Korea. Animals were slaughtered in 3 groups of 6 animals over a 3-day period. On each slaughter day, 6 animals were transported to the NIAS abattoir, and fasted for approximately 12 hr, but with access to water prior to slaughter. To manage postmortem glycolysis, the cattle were stimulated by using a low voltage electrical stimulation system (45 V, 100 msec on and 12 msec off, 36 pulses per sec, applied during bleeding for 10-20 sec).

In Australia, 18 Angus steers (ca. 24 months of age; 150 days on a high concentrate ration before slaughter; 342-423 kg carcass weight) were transported 1.5 hr from the

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Received July 26, 2007; Revised November 28, 2007;
Accepted December 3, 2007

feedlot to a commercial abattoir at Bunbury, WA, where the animals were kept off feed, but with access to water overnight, before they were slaughtered. The cattle were slaughtered on the following day. Data from previous slaughters with similar cattle showed that the rate of pH/temperature fall was very fast, and so the immobilizer and rigidity probe were switched off.

The sensory testing samples were prepared using the same protocol with Australian Angus (10,11). Carcasses were deboned, and *longissimu dorsi* (LD), *semimembranosus* (SM), and *triceps brachii* (TB) muscles were removed and vacuum-packed on the following day, and aged for 7 days at a 1°C chiller. After aging, fat and epimysium were removed from the muscles, and 50×70×25 mm steaks 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 75×20×4 mm, parallel to the fiber direction. The sensory samples were vacuum-packed separately and stored at −20°C until analysis. Samples prepared in Australia were transported to Korea (NIAS, Suwon) in frozen state, and kept at −20°C until use. Both beef samples of Australian Angus and Korean Hanwoo were prepared with the same manner and stored in frozen state for 20 days until consumer sensory testing.

pH and temperature Muscle temperature and pH were measured by using a portable needle-tipped combination electrode (pH-K21; NWKBinär, Landsberg, Germany) at approximately a 15-min interval in the center of the 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, approximately 24 hr postmortem. Intramuscular fat content was determined by a microwave-solvent extraction method described by the Association of Official Analytical Chemists (AOAC) (12).

Sensory evaluation of grill and Korean BBQ samples The design comprised 18 Korean and 18 Australian carcasses × 3 cuts × 2 cooking techniques, which provided a total of 432 samples (216 Hanwoo beef and 216 Australian beef) and evaluated by Korean consumers in Korea and a total of 216 samples (216 Australian beef) were evaluated by Australian consumers in Australia. Consequently, a total of 6,480 testing samples ([648 samples × 10 consumers per sample] / 6 samples per consumer) were involved by 1,080 consumers for sensory testing; 4,320 samples were evaluated by 720 Korean consumers in Korea (432 samples × 10 consumers; 720 consumers × 6 samples) and 2,160 samples were evaluated by 360 Australian consumers in Australia (216 treatment sample × 10 consumers; 360 consumers × 6 samples). The 6 samples for each consumer were allocated to session and serving order within session by using a latin square design.

Consumers were recruited from government institutions and universities in the Gyeonggi region. Socio-economic details were recorded for each consumer. For the testing sessions, venues were selected based on convenience of the consumer groups; the tests were conducted in an informal setting. There were 2 types of cooking methods used in this experiment.

Using the methods described by Gee and Polkinghorne (11), the Korean-style BBQ thin slice cooking was performed. The BBQ strips were thawed to approximately 4°C. Individual strips were cooked by placing these on the tin plate equipped with a water jacket (ca. 245-255°C). The strips were 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 Gee *et al.* (10). Briefly, 10 thawed steaks (ca. 4°C) were grilled at 220-230°C by using a double surface Silex Griller (S-tronic steaker, Silex Elektrogeräte GmbH, Hamburg, Germany) 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.

Sensory evaluation was performed by the staff of the NIAS. A supervisor from the Australian Sensory Solution traveled to Korea to train the NIAS staff on the Meat Standard Australia (MSA) protocols and observe the testing process to ensure its uniformity in all of the testing sessions. At each session, every consumer was served a total of 7 samples (the first was a common link used to standardize consumers with the sensory protocol, followed by 6 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 4 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). Australian beef were prepared with the same manner and sensory testing was performed with the same methodology in Australia.

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.* (13). An aliquot of total lipid extract was methylated as described by Morrison and Smith (14). Fatty acid methyl esters were analyzed by a gas chromatograph (Star 3600; Varian Technologies, Palo Alto, CA, USA) fitted with a fused silica capillary column, omegawax 205 (30 m×0.32 mm i.d., 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 based on the total peak area.

Statistical analysis The 10 consumer scores from each sample were averaged. The relationship between least square means for fatty acids and the sensory characteristics were estimated by using a linear model containing consumer group, animal, and muscle as fixed effects. Models included fixed effects of beef origin, cut, consumer group, and their interactions. Each sensory characteristic and fatty acid were tested by using the ANOVA procedure. Fisher's least significance difference (LSD) was used for assessing the differences in means according to cut or consumer group. Correlation analysis was done to find the linear relation between sensory variable and fatty acid in each consumer group. In order to establish different cluster of consumers, a hierarchical cluster analysis was used based on 4 sensory characteristics over all the consumers with the statistical software R (15). The Ward method was adopted to find clusters by minimizing the within sum of squares in each cluster. 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, all the consumers were classified into 3 clusters, and the cluster profiles of the sensory characteristics were reported for the comparison of the 3 clusters. After clustering the differences in the fatty acids were identified with the implementation of one-way ANOVA and F-tests in each consumer group such as Korean Angus, Korean Hanwoo and Australian Angus group. Stepwise discriminant analysis with SAS procedure (16), PROC STEPDISC was done to find the most significant fatty acid to discriminate 3 clusters in each consumer group.

Results and Discussion

Carcass traits and factors affecting sensory characteristics The Australian Angus and the Korean Hanwoo beef used in this study had similar carcass weights and ages as summarized in Table 1. However, the Hanwoo beef has lower subcutaneous fat depth, but higher marble scores (measured by USDA scoring system) than those of the Australian carcasses. This difference could be attributed to the type of feeding system at the early stage employed in the 2 countries. The Korean Hanwoo steers were grown under the long-term feeding program while the Australian Angus steers were kept mostly on grass feeding at the early stage before this experiment. All carcasses reached normal ultimate pH, with an average of 5.45 at 24 hr postmortem.

Previous workers have found that changes in fatty acid composition were related to fatness, age, carcass weight, and rate of fat deposition (17,18).

Tenderness was significantly different depending on beef origin and cut ($p<0.05$), but it was not different among the consumer groups (Table 2). Also, the consumer × cut interaction was highly significant for tenderness, flavor likeness, and overall likeness ($p<0.01$). The juiciness, like flavor, and overall liking scores were also significantly different among consumer groups, beef origin, and cut ($p<0.05$). However, several studies have shown that the palatability and flavor preference for cooked meat depended on the previous eating habit of the consumer group (19-21).

Cluster grouping of preference by fatty acids, beef origin, and consumer group The cluster diagram showed the hierarchy of clusters (Fig. 1). For each consumer group and beef origin, analysis of variance was done with sensory variables and fatty acids (Table 3). After clustering, 3 clusters were identified in each consumer and breed group and the statistical inference was done groupwise. The coordinates of each consumer obtained in the 4-dimensions of the sensory characteristics were used as clustering variables. The clusters were in a descending order in terms of sensory mean scores, such that cluster 1 had high scores for 4 factors, while cluster 3 had lowest mean scores for tenderness, juiciness, like-flavor, and overall likeness, respectively.

Table 1. Carcass traits for Australian and Korean cattles used in the experiment (n=18 carcasses for each treatment)

Carcass traits	Korean Hanwoo carcasses		Australian Angus carcasses	
	Mean	SD[1)]	Mean	SD
Carcass weight (kg)	371	38.2	386	25.3
Fat depth (12/13th, mm)	8.8	3.14	15.7	4.81
Marbling scores (USDA)	593.0	60.0	362.6	66.0
Intramuscular fat (%)	11.29	3.36	5.72	2.64
pH ultimate	5.46	0.07	5.45	0.03

[1)]Standard deviation.

Table 2. Effect of beef origin, evaluation consumer group, and cut on sensory characteristics[1)]

	Tenderness	Juiciness	Like-flavor	Overall likeness
Consumer group	3.00	4.02*	9.29**	8.76**
Beef origin	29.86***	4.55*	19.85***	22.78***
Cut	119.69 ***	79.94***	45.64***	98.82***
Consumer × cut	6.29**	1.53	6.89**	5.78**
Beef origin × cut	0.5	2.76	0.52	1.57

[1)]F-ratio statistic for one-way ANOVA; *$p<0.05$, **$p<0.01$, *** $p<0.001$.

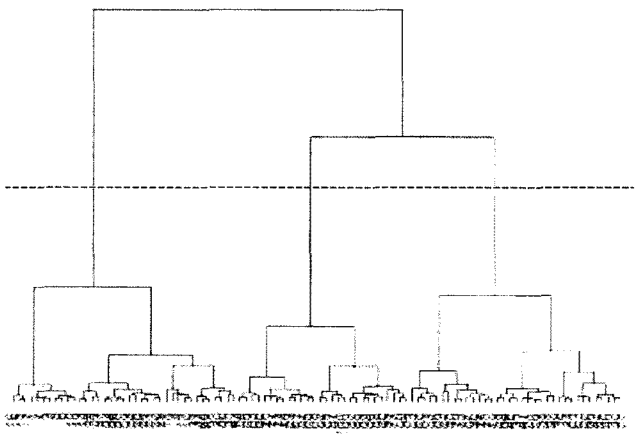

Fig. 1. Hierarchical cluster analysis based on tenderness, juiciness, like-flavor, and overall likeness. The broken line shows the cluster selection used.

Fatty acids such as C14:0, C16:0, C16:1(n7), C18:0, C18:2(*n*-6), C18:3(*n*-3), C20:3(*n*-6), C20:4(*n*-6), C20:5(*n*-3), C22:4(*n*-6), C22:5(*n*-3), n3 and n6 significantly affected the Korean consumers' preference; while most of fatty acids except for C20:5(*n*-3) and C22:5(*n*-3) was not related to the Australian consumers' preference (Table 3). There were several studies that fatty acids were significantly related to the meat flavor profiles or sensory properties (22-24). According to the previous publication of this study, the saturated fatty acids, C16:0 and C18:0, were positively correlated with all sensory traits, while the unsaturated fatty acids such as C18:2(*n*-6), C20:2(*n*-6), C20:3(*n*-6), C20:4(*n*-6), and C22:4(*n*-6) were negatively correlated with all sensory traits ($p<0.05$) (r values of less than 0.5) (25).

Table 3. Means of tenderness, juiciness, like-flavor, and overall likeness clustered for all consumers by Ward method and ANOVA results of comparing cluster means of fatty acids

Consumer	Korean consumer						Australian consumer		
Breed	Angus			Hanwoo			Angus		
Cluster	1	2	3	1	2	3	1	2	3
Numbers	84	62	70	53	58	105	86	59	71
Tenderness[1)]***	75.2[2)] (5.93)	62.75 (5.88)	47.21 (7.80)	75.20 (5.84)	61.60 (5.21)	43.85 (8.76)	73.57 (5.44)	61.17 (5.20)	46.09 (8.59)
Juiciness[1)]***	69.95 (7.37)	59.64 (6.04)	54.66 (6.69)	69.59 (5.18)	62.24 (8.11)	54.24 (7.41)	72.56 (5.38)	62.68 (6.16)	50.54 (8.86)
Like-flavor[1)]***	67.92 (6.49)	61.89 (4.38)	56.31 (6.24)	65.81 (4.64)	60.75 (4.06)	55.14 (5.56)	71.02 (6.12)	61.92 (3.24)	53.32 (5.94)
Overall likeness[1)]***	71.59 (5.16)	62.63 (3.91)	50.99 (5.89)	71.77 (4.21)	61.47 (4.03)	48.96 (7.08)	73.01 (4.93)	62.14 (3.57)	49.77 (7.05)
Fatty Acids	F-ratio[3)]			F-ratio[3)]			F-ratio[3)]		
C14:0	0.66			7.02** (1 2) (3)			1.15		
C16:0	6.33** (1 2) (3)[4)]			6.40** (1) (2 3)			2.99		
C16:1(*n*-7)	3.79* (1) (2 3)			4.11* (1) (2 3)			2.76		
C18:0	5.21** (1 2) (3)			8.36*** (1) (2 3)			2.69		
C18:1(*n*-9)	2.75			0.24			1.03		
C18:1(*n*-7)	0.13			0.96			0.28		
C18:2(*n*-6)	4.05* (1) (2 3)			10.08*** (1) (2 3)			1.35		
C18:3(*n*-6)	1.01			1.12			0.36		
C18:3(*n*-3)	4.82** (1) (2 3)			7.49*** (1 2) (3)			1.85		
C20:1(*n*-9)	2.06			2.41			0.32		
C20:2(*n*-6)	1.13			2.75			0.76		
C20:3(*n*-6)	9.38*** (1) (2 3)			11.36*** (1 2) (3)			2.62		
C20:4(*n*-6)	11.79*** (1) (2 3)			14.86*** (1 2) (3)			1.74		
C20:5(*n*-3)	12.06*** (1) (2 3)			0.10			4.77** (1) (2 3)		
C22:4(*n*-6)	6.25** (1) (2 3)			7.59*** (1 2) (3)			0.42		
C22:5(*n*-3)	11.70*** (1) (2 3)			3.75* (1 2) (3)			4.66* (1) (2 3)		
SFA[5)]	7.16*** (1 2) (3)			10.20*** (1) (2 3)			2.85		
USFA[5)]	7.16*** (1 2) (3)			10.21*** (1) (2 3)			2.85		
MUFA[5)]	3.91* (1 2) (3)			1.51			1.88		
PUFA[5)]	9.08*** (1) (2 3)			12.62*** (1) (2 3)			2.63		
N3	12.31*** (1) (2 3)			6.96** (1 2) (3)			4.66* (1) (2 3)		
N6	7.53*** (1) (2 3)			12.58*** (1 2) (3)			2.15		
MUFA:SFA	4.81** (1 2) (3)			6.04** (1) (2 3)			2.16		
PUFA:SFA	9.24*** (1) (2 3)			13.38*** (1 2) (3)			2.49		

1)0: very tough, very dry, dislike extremely; 100: very tender, very juicy, like extremely.
2)Means±SD.
3)F-ratio statistic for one-way ANOVA; *$p<0.05$, **$p<0.01$, ***$p<0.001$.
4)(ab) means that cluster a and cluster b can be combined into the same group ($p>0.05$).
5)SFA, saturated fatty acids; USFA, unsaturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

Fatty acid composition among the ruminants differed in terms of diet condition. Studies with beef and lamb showed that the concentrations of 18:3 and 20:5 in muscle phospholipids are higher when animals have been fed with grass than fed with grain-based (concentrate) diets (23). Cho *et al.* (25) reported that Australian Angus beef had significantly higher *n*-3 poly unsaturated fatty acids (PUFA) than that of the Korean Hanwoo beef for the 3 muscles (LD, TB, and SM), and that Korean Hanwoo contained higher *n*-6 PUFA ($p<0.05$) in the previous publication. Total contents of *n*-3 PUFA which was reflected through a relatively greater deposition for long chain derivatives for C18:3 were significant factor for the preference of both consumer groups (Table 3). It should be noted that the Australian Angus used in the experiment were on grass-feeding for a certain period of time so that this must have contributed to the difference in fatty acid content of the meat thereby, altering the sensory qualities of the beef from the two countries. Fatty acids can affect the sensory traits especially for Korean consumers such that most of the fatty acids are more correlated with the sensory variables for the Korean consumers than the

Table 4. Stepwise F-ratios[1)] of fatty acids for discriminant analysis of 3 clusters

Step	Number		Partial R-square	F-ratio	Pr >F	Wilks' lambda[2)]	Pr<lambda
	Entered	Removed					
Korean-Angus group							
1	**C20:5(*n*-3)**	-	**0.1017**	**12.06**	**<0.0001**	**0.8983**	**<0.0001**
2	C22:4(*n*-6)	-	0.0208	2.25	0.1081	0.8796	<0.0001
Korean-Hanwoo group							
1	**C20:4(*n*-6)**	-	**0.1225**	**14.86**	**<0.0001**	**0.8775**	**<0.0001**
2	**C18:0**	-	**0.0529**	**5.91**	**0.0032**	**0.8312**	**<0.0001**
3	C20:5(*n*-3)	-	0.0354	3.88	0.0222	0.8017	<0.0001
4	C20:1(*n*-9)	-	0.0281	3.04	0.0500	0.7791	<0.0001
5	C20:3(*n*-6)	-	0.0219	2.34	0.0985	0.7620	<0.0001
Australian-Angus group							
1	**C20:5(*n*-3)**	-	**0.0429**	**4.77**	**0.0094**	**0.9571**	**0.0094**

[1)]Each variable considered for entry or removal: partial R-square, the squared (partial) correlation, the F statistic, and Pr >F, the probability level, from a one-way ANOVA.
[2)]Wilks' lambda is the likelihood ratio statistic for testing the hypothesis that the means of the classes on the selected variables are equal in the population. Lambda is close to zero if those groups are well separated. Wilks' lambda values in Table 3 shows that those variables significantly discriminate 3 clusters.

Australian consumers even when both consumers tasted the same origin of Australian Angus beef. Korean consumers had also significant relationship with fatty acids when they evaluated the Korean Hanwoo. Therefore, fatty acid composition of ruminant meats can influence the flavor or sensory properties which contributed to the eating satisfaction of the consumer groups from different countries. Oliver *et al.* (26) reported that the preference of taste panelists for meat must have depended on their previous cultural experience and eating habit. In this study, Korean consumers were more accustomed to the taste of Hanwoo beef which were mostly produced in feedlot condition, and they prefer the beef with high intramuscular fat while the Australian consumers were used to grass-fed beef. Thompson (5) reported that Australian consumers were not affected by the intramuscular fat contents for their palatability of beef, but leanness is the more important issue. Hwang *et al.* (4) reported that the preference of Korean consumers was related to the fatty acids composition of beef products derived from grain-fed Hanwoo, grain-fed Wagyu, and grass fed Angus ($p<0.05$). However, different fatty acids played an important role for Korean consumers in determining the palatability clustering with different beef origin such as C20:5(*n*-3) for Australian Angus, and C20:4(*n*-6) and C18:0 for Korean Hanwoo beef (Table 4).

Therefore, the result indicated that the fatty acids compositions of beef had a significant relationship with the palatability of Korean consumers and specific type of fatty acids discriminated the palatability based on beef origin.

Acknowledgments

We are grateful to the Meat and Livestock Australia (MLA), Australia and the National Institute of Animal Science (NIAS), Korea for their financial support, as well as the staff of the Sensory Solution of MLA staff and NIAS for their organizing consumers and running the sensory evaluations.

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