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ARTICLE

Comparisons of Beef Fatty Acid and Amino Acid Characteristics between Jeju Black Cattle, Hanwoo, and Wagyu Breeds

Seung-Hoon Lee[1,†], Chung-Nam Kim[2,†], Kyoung-Bo Ko[2], Se-Pill Park[2], Ho-Kyoung Kim[3], Jun-Mo Kim[4,*], and Youn-Chul Ryu[2,*]

[1]Division of Biotechnology, College of Life Science, Korea University, Seoul 02841, Korea
[2]Division of Biotechnology, SARI, Jeju National University, Jeju 63243, Korea
[3]Division of Food Nutrition and Culinary Art, Dong-Eui Institute of Technology, Busan 47230, Korea
[4]Department of Animal Science and Technology, College of Biotechnology and Natural Resources, Chung-Ang University, Anseong 17546, Korea

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***Corresponding author** : Jun-Mo Kim
Department of Animal Science and Technology, College of Biotechnology and Natural Resources, Chung-Ang University, Anseong 17546, Korea
Tel: +82-31-670-3263
Fax: +82-31-675-3108
E-mail: junmokim@cau.ac.kr

Youn-Chul Ryu
Division of Biotechnology, Jeju National University, Jeju 63243, Korea
Tel: +82-64-754-3332
Fax: +82-64-725-2403
E-mail: ycryu@jejunu.ac.kr

***ORCID**
Seung-Hoon Lee
https://orcid.org/0000-0001-6703-7914
Chung-Nam Kim
https://orcid.org/0000-0003-0833-0111
Kyoung-Bo Ko
https://orcid.org/0000-0002-5837-0974
Se-Pill Park
https://orcid.org/0000-0002-6965-7831
Ho-Kyoung Kim
https://orcid.org/0000-0002-7995-1129
Jun-Mo Kim
https://orcid.org/0000-0002-6934-398X
Youn-Chul Ryu
https://orcid.org/0000-0001-8940-624X

† These authors contributed equally to this study.

Abstract Jeju black cattle are known as one of Korea's traditional cattle. However, Hanwoo is more well-known to Korean meat consumers as representative beef cattle. Despite the popularity of these two breeds, comparison of the nutritional characteristics between Jeju black cattle and Hanwoo have not been studied. Here, we compared the fatty acid and amino acid characteristics between two Korean traditional cattle and Wagyu breeds. A total of 62 cattle were used in this study. The Jeju black cattle beef had significantly higher unsaturated fatty acids than Hanwoo ($p<0.05$). Savory fatty acids, including oleic acid were also higher than in Hanwoo cattle ($p<0.05$). The negative flavor fatty acids, such as palmitic acid were significantly lower than in Hanwoo ($p<0.001$). On the other hand, linoleic acid which imparts a negative flavor was higher than Hanwoo ($p<0.05$). Amino acids, including alanine and glutamine, usually representative of the umami taste were present in significantly higher proportions in Jeju black cattle ($p<0.05$). In addition, bitter tasting amino acids, including valine, leucine, isoleucine, and methionine were lower in Jeju black cattle beef than in Hanwoo ($p<0.05$, $p<0.001$, $p<0.001$, and $p<0.001$ each). Taken together, our results suggest that Jeju black cattle beef had higher savory flavor and umami taste which affected consumers preference for the meat.

Keywords beef, nutritional characteristics, Jeju black cattle, Hanwoo, Wagyu

Introduction

Based on Korean historical records, Korean native cattle have lived on the Korean peninsula since the fourth century (Kim and Lee, 2000). The Korean native cattle have traditionally included four cattle breeds, composed of three coat color patterns (Jo et al., 2012; Lee et al., 2014). The three color patterns are a brown or red, a black-striped brown, and two black color breeds (Lee et al., 2014). The Korean native cattle breeds were used as working cattle until the 1960s. With the development of farming technology, Korean native cattle became used as beef meat (Kim and Lee, 2000; Lee et al., 2014). The well-known Hanwoo cattle breed has the largest population in South Korea. The other three non-brown or red color breeds have smaller populations. Among the minor breeds, Jeju black cattle live only on Jeju Island (Han et al., 2011).

Jeju black cattle beef were a rare gift given to the king in the Chosun era. The king only could eat that beef on his birthday, New Year's Day, and on Memorial Day of the royal family. Presently, Jeju black cattle beef is available at specialty butcher shops due to development of production technology. However, people recognize Hanwoo as the representative beef meat cattle of Korea and favor it for roasting. Wagyu is the popular Japanese cattle breed for its texture, flavor, and tenderness. The roasted beef is a popular meat food in South Korea. Consumers prefer the palatability and flavor from its marbled fat (Frank et al., 2016). Because of these preferences, beef consumption has increased every year (Korea Meat Industries Association, 2000). The flavor of beef meat is derived from its fatty acid content (Frank et al., 2016; Lorido et al., 2015). Fatty acid content is an important factor in the beef meat industry (Frank et al., 2016; Melton et al., 1982). The type and amount of fatty acids in beef meat have a great effect on quality perception and sensory characteristics, such as taste, tenderness, and flavor (Enser et al., 1996; Frank et al., 2016; Hocquette et al., 2014).

Fatty acids are categorized into saturated fatty acids (SFA) and unsaturated fatty acids (UFA). The SFAs are composed of single bond fatty acid chains, and therefore are usually solids room temperature. On the other hand, UFAs are generally liquids at room temperature because their molecular structure is not linear. Moreover, a previous study reported that the UFAs have a key role in meat flavor (Elmore et al., 1999). In another study, the fatty acid and amino acid characteristics of cattle breeds, including Hanwoo were reported (Hwang and Joo, 2017). However, a comparison of these characteristics between Hanwoo and Jeju black cattle was not performed. Through identification of differences between these two Korean traditional cattle breeds the quality of Korean beef meat production can be enhanced. In this study, we examined the fatty acid and amino acid characteristics of Hanwoo and Jeju black cattle beef and suggest the unique nutritional characteristics of Jeju black cattle beef that have made it a popular meat choice in Korea.

Materials and Methods

Meat samples

A total of 62 cattle of the Hanwoo (n=28; females (F)=11, castrated males (CM)=16), Jeju black cattle (n=25; F=8, CM=17), and Wagyu (CM=10) breeds were used in this study. Hanwoo and Jeju black cattle were raised in the same farm and same feeding condition and slaughtered on Jeju Island. After slaughter, the *longissimus dorsi* (LD) muscles were sampled and cut into 2.5 cm thick steaks. The muscle samples were vacuum-packed and stored at 4℃ until 41 days postmortem. Wagyu beef was commercial meat imported from Australia and also vacuum-packed and stored at 4℃ until 41 days postmortem.

Fatty acids and amino acids analysis

To compare the nutritional content, fatty acid and amino acid composition was measured. The fatty acids and amino acids were measured by gas chromatography-flame ionization detector (GC). A total of 37 fatty acids were measured using 25 g of muscle collected from each animal. The samples were methylated with 14% BF3-Methanol and diluted using 1 mL isooctane. The column used was 100 mm×0.25 mm×0.2 μm (Supelco TMSP-2560, Sigma-Aldrich®, USA). The carrier gas was nitrogen at 0.8 mL/min. The injector and the detector were tested at 240℃ and 285℃ each. The split ratio was varied between 100 and 1. The standard solution of fatty acids was a 0.1 g fatty acid methyl ester mixture (SUPELCOTM 37Component FAME Mix, Bellefonte, PA, USA) diluted to 100 mg/mL in isooctane. The GC retention time of the standard solution is presented in Table S1 and Table S2.

Statistical analysis

The association between cattle traits were measured using the general linear model (GLM) procedure (SAS; SAS Institute, Inc., USA). To compare the mean values between the cattle breeds, Duncan's multiple range test was used. A value of $p<0.05$ was considered statistically significant.

Results and Discussion

In this study, we performed fatty acid composition analyses of Hanwoo, Jeju black cattle, and Wagyu breed using a GC method. The fatty acids compositions are presented in Table 1. Palmitic acid showed a significant difference between Hanwoo and Jeju black cattle. Hanwoo beef had much more palmitic acid than Jeju black cattle ($p<0.001$). In a previous study, palmitic acid, an SFA, had a negative effect on beef meat flavor (Westerling and Hedrick, 1979). Consumers prefer the good flavor of fatty acids in beef fat marble (Kim et al., 1999). Therefore, Jeju black cattle with relatively less palmitic acid, is a popular choice of consumers. There was a significant difference in oleic acid and linoleic acid among breeds ($p<0.05$). Jeju black cattle showed the highest proportion of oleic acid and contained more oleic acid and linoleic acid than Hanwoo. These fatty acids are representative fatty acids in beef meat (Dryden and Maechello, 1970; Enser et al., 1996; Westerling and Hedrick, 1979). Oleic acid has been reported to have a role in good meat flavor and savory taste (Dryden and Maechello, 1970). The savory taste and flavor are important traits for meat consumers, thus a rich oleic acid content can make meat taste better.

Linoleic acid was reported to cause a negative flavor in meat (Westerling and Hedrick, 1979). Jeju black cattle beef may be less flavorful than Hanwoo meat because of linoleic acid, but the absolute amount of linoleic acid is less than the palmitic acid amount. Therefore, its effect to decrease flavor in Jeju black cattle beef could be expected to be small. Jeju black cattle showed a lower proportion of SFAs than Hanwoo ($p<0.001$). SFAs are known to be the main culprit in hyperlipidemia and hypercholesterolemia (Bingham et al., 2002; Micha and Mozaffarian, 2010; Mozaffarian et al., 2010). These conditions are reported to cause cardiovascular disease and diabetes (Bingham et al., 2002; Micha and Mozaffarian, 2010). Therefore, lower proportions of SFAs are more preferable. In addition, the consumers' preference has changed from flavor to health (Joo et al., 2017). Therefore, the lower SFAs in Jeju black cattle beef are likely to be preferred by consumers.

In contrast to the SFA ratio, the UFA ratio, including mono-UFA (MUFA) and poly-UFA (PUFA) was higher in Jeju black cattle than Hanwoo (MUFA: $p<0.01$, PUFA: $p<0.05$). The UFA ratio is also known to be associated with better health (Cross et al., 2007; Kontogianni et al., 2008). In previous studies, a high UFA ratio prevented cardiovascular disease, a common disease with a high mortality rate (Kim et al., 2018; Rawshani et al., 2017). Hence, the Jeju black cattle could be a better choice for consumers who consider health a priority.

To compare the nutritional characteristics between Hanwoo, Jeju black cattle, and Australian Wagyu breed, we tested the amino acid composition of meat using GC. The amino acid composition results are presented in Table 2. The amino acid composition was significantly different among breed. Jeju black cattle had higher amounts of alanine than Hanwoo ($p<0.05$).

Table 1. Comparison to fatty acids composition between Jeju Black, Hanwoo and Wagyu cattle

Fatty acids	Hanwoo		Jeju Black cattle		Wagyu (n=10)	Significance[1)]
	Female (n=11)	Castrated male (n=16)	Female (n=8)	Castrated male (n=17)		
C14:0 (Myristic acid)	3.30±0.69[2)]	3.50±0.91	2.35±0.25	2.38±0.56	3.36±0.34	ns
C14:1 (Myristoleic acid)	0.91±0.47	0.99±0.42	1.06±0.61	0.93±0.04	1.03±0.21	ns
C15:0 (Pentadecanoic acid)	0.25±0.05	0.20±0.08	0.00±0.00	0.22±0.10	0.13±0.11	ns
C16:0 (Palmitic acid)	28.74±2.29[a]	26.83±1.86[ab]	21.23±1.87[b]	22.52±1.41[b]	24.80±0.29[b]	***
C16:1 (Palmitoleic acid)	4.10±0.49	4.37±0.85	5.07±2.16	4.45±1.07	5.45±1.40	ns
C17:0 (Heptadecanoic acid)	0.66±0.18	0.30±0.25	0.72±0.42	0.39±0.20	0.80±0.21	ns
C17:1 (Heptadecenoic acid)	0.59±0.06	0.82±0.08	0.94±0.12	0.64±0.07	0.67±0.03	ns
C18:0 (Stearic acid)	11.13±0.66	10.37±0.99	8.44±1.73	9.45±1.79	10.05±1.82	ns
C18:1n-9 (*Cis*-Oleic acid)	47.20±4.03[b]	49.75±3.14[ab]	56.34±5.66[a]	53.95±4.48[a]	49.91±1.99[ab]	*
C18:2n-6 (*Cis*-Linoleic acid)	1.95±0.48[b]	1.94±0.39[b]	2.56±0.46[a]	2.66±0.49[a]	2.62±0.45[a]	*
C20:0 (Arachidic acid)	0.04±0.00	0.02±0.00	0.00±0.00	0.00±0.00	0.00±0.00	ns
C18:3n-6 (y-Linolenic acid)	0.05±0.01	0.03±0.01	0.00±0.00	0.03±0.01	0.00±0.00	ns
C18:3n-3 (Linolenic acid)	0.10±0.03	0.09±0.01	0.00±0.00	0.13±0.05	0.14±0.06	ns
C20:1 (*Cis*-11-Eicosenoic acid)	0.36±0.23	0.41±0.11	0.47±0.07	0.61±0.29	0.24±0.01	ns
C20:2 (*Cis*-11,14-Eicosadienoic Acid)	0.00±0.00	0.00±0.00	0.00±0.00	0.65±1.46	0.00±0.00	ns
C20:3n-6 (*Cis*-8,11,14-Eicosatrienoic acid)	0.15±0.06	0.13±0.08	0.37±0.21	0.28±0.02	0.24±0.03	ns
C20:4n-6 (Arachidonic acid)	0.47±0.32	0.25±0.23	0.45±0.40	0.71±0.68	0.56±0.05	ns
SFA (%)	44.22±3.23[a]	41.31±3.11[a]	32.74±4.17[b]	35.09±3.76[b]	39.28±3.62[ab]	***
MUFA (%)	53.16±3.16[b]	56.34±2.85[b]	63.88±3.79[a]	60.58±3.98[a]	57.30±3.49[ab]	**
PUFA (%)	2.62±0.66[b]	2.35±0.67[b]	3.38±0.68[a]	4.33±1.15[a]	3.42±0.69[a]	*

[1)] Significance levels for breeds: ns, not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.
[2)] Means±SD.
[a,b] Different superscript letters indicate significant differences between breeds at $p<0.05$.
SFA, saturated fatty acids; MUFA, mono-unsaturated fatty acids; PUFA, poly-unsaturated fatty acids.

The amino acid alanine is associated with a sweet taste in meat (Shallenberger and Acree, 1967), so Jeju black cattle beef could be perceived to be sweeter than Hanwoo meat. Glutamic acid was higher in Hanwoo than Jeju black cattle ($p<0.01$). Glutamic acid is known for its umami taste, the fifth basic taste (Kirimura et al., 1969; Lindemann, 1996; Nelson et al., 2002). Therefore, the consumers might perceive more umami taste in Hanwoo beef.

Table 2. Comparison to amino acids composition between Jeju Black, Hanwoo and Wagyu cattle

Amino acids	Hanwoo		Jeju Black cattle		Wagyu (n=10)	Significance[1)]
	Female (n=11)	Castrated male (n=16)	Female (n=8)	Castrated male (n=17)		
Alanine	16.97±1.27[b2)]	22.54±2.98[a]	22.41±3.49[a]	23.71±3.98[a]	22.89±3.18[a]	*
Asparagine	2.05±0.83	1.32±0.37	1.42±0.07	1.80±0.51	1.90±0.24	ns
Aspartic acid	1.76±0.06[a]	1.64±0.11[a]	0.00±0.00[b]	1.25±0.31[b]	0.05±0.02[b]	**
Cysteine	0.98±0.03[b]	0.46±0.03[b]	1.87±0.14[a]	0.58±0.01[b]	0.20±0.01[b]	*
Glutamic acid	4.01±1.16[a]	2.39±0.42[b]	1.68±0.09[b]	2.08±0.95[b]	2.02±0.36[b]	**
Glutamine	11.70±1.50[b]	25.76±2.62[a]	33.86±8.41[a]	25.47±7.34[a]	25.76±2.62[a]	*
Glycine	5.81±0.20	5.80±1.07	5.05±0.40	6.26±1.64	5.61±1.14	ns
Histidine	3.14±0.45	2.59±0.52	3.53±1.20	3.34±1.49	3.51±1.22	ns
Isoleucine	5.16±0.43[a]	2.96±0.74[b]	2.20±0.38[b]	2.72±0.73[b]	2.67±0.56[b]	***
Leucine	11.07±0.72[a]	6.22±1.36[b]	4.55±0.65[b]	5.59±1.61[b]	6.05±1.20[b]	***
Lysine	1.64±0.17[b]	1.64±0.31[b]	2.68±0.37[a]	2.18±0.89[ab]	2.02±0.37[ab]	*
Methionine	5.90±0.28[a]	3.80±0.45[b]	2.47±0.30[c]	3.29±0.93[bc]	3.67±0.43[b]	***
Ornithine	1.48±0.44	1.18±0.18	1.87±1.15	0.93±0.39	1.73±0.25	ns
Phenylalanine	7.27±0.39[a]	4.64±0.75[b]	3.65±0.62[b]	4.60±1.00[b]	4.64±0.78[b]	**
Proline	1.95±0.04[b]	2.61±0.23[a]	2.42±0.33[ab]	2.65±0.33[a]	2.63±0.31[a]	*
Serine	6.05±0.07[a]	3.94±0.60[b]	2.62±0.01[b]	3.81±1.39[b]	3.91±0.89[b]	**
Threonine	4.98±0.17[a]	2.82±0.68[b]	1.95±0.28[b]	2.74±1.00[b]	2.84±0.88[b]	**
Tyrosine	1.04±0.13[b]	2.66±0.63[a]	2.32±0.06[a]	2.41±0.64[a]	2.69±0.76[a]	**
Valine	6.32±0.82[a]	4.50±0.92[ab]	3.14±0.65[b]	3.93±1.42[b]	4.43±1.42[ab]	*

[1)] Significance levels for breeds: ns, not significant, * p<0.05, ** p<0.01, *** p<0.001.
[2)] Means±SD.
[a,b] Different superscript letters indicate significant differences between breeds at p<0.05.

The amino acids imparting bitter tastes, including valine, leucine, isoleucine, and methionine were higher proportions in Hanwoo than in Jeju black cattle (p<0.05, p<0.001, p<0.001 and p<0.001 each). Compared to the other basic tastes of sweet, sour and salty, the bitter taste remains longer (Kato et al., 1989; Nishimura and Kato, 1988; Solms, 1969). In addition, a previous study showed that people were displeased by a single bitter taste (Drewnowski and Gomez-Carneros, 2000). Therefore, Jeju black cattle could be more preferable than Hanwoo beef.

Conclusion

Jeju black cattle had much more UFA and savory amino acids, including alanine, than Hanwoo and Wagyu breeds. The UFAs, such as oleic acid, provided rich favor. In addition, these UFAs could reduce blood cholesterol. The savory amino acids, such as alanine may affect consumer preference because of the savory taste they impart to beef.

Taken together, our results suggest that Jeju black cattle beef had higher savory flavor and umami taste which affected consumers preference for the meat.

Conflict of Interest

The authors declare no potential conflict of interest.

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Author Contributions

Conceptualization: Park SP. Methodology: Ko KB. Writing - original draft: Lee SH, Kim CN. Writing - review & editing: Lee SH, Kim CN, Ko KB, Park SP, Kim HK, Kim JM, Ryu YC.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

Supplementary Materials

Supplementary materials are only available online from: https://doi.org/10.5851/kosfa.2019.e33.

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Supplementary Materials

Table S1. Gas chromatography retention time of standard fatty acids

Fatty acids		Retention time
C4:0	Butyric acid	13.980
C6:0	Caproic acid	15.990
C8:0	Caprylic acid	19.301
C10:0	Capric acid	23.774
C11:0	Undecanoic acid	26.305
C12:0	Lauric acid	28.719
C13:0	Tridecanoic acid	31.214
C14:0	Myristic acid	33.580
C14:1	Myristoleic acid	35.554
C15:0	Pentadecanoic acid	35.904
C15:1	*Cis*-10-Pentadecenoic acid	37.804
C16:0	Palmitic acid	38.167
C16:1	Palmitoleic acid	39.679
C17:0	Heptadecanoic acid	40.271
C17:1	*Cis*-10-Heptadecenoic acid	41.757
C18:0	Stearic acid	42.385
C18:1n-9,trans	Elaidic acid	43.238
C18:1n-9,cis	Oleic acid	43.634
C18:2n-6,trans	Linolelaidic acid	44.610
C18:2n-6,cis	Linoleic acid	45.499
C20:0	Arachidic acid	46.308
C18:3n-6	y-Linolenic acid	46.918
C20:1	*Cis*-11-Eicosenoic acid	47.395
C18:3n-3	Linolenic acid	47.661
C21:0	Heneicosanoic acid	48.120
C20:2	*Cis*-11,14-Eicosadienoic acid	49.157
C20:2	Behenic acid	49.982
C20:3n-6	*Cis*-8,11,14-Eicosatrienoic acid	50.469
C20:1n-9	Erucis acid	50.970
C20:3n-3	*Cis*-11,14,17-Eicosatrienoic acid	51.178
C20:4n-6	Arachidonic acid	51.502
C23:0	Tricosanoic acid	51.675
C22:2	*Cis*-13,16-Docosadienoic acid	52.638
C24:0	Lignoceric acid	53.518
C20:5n-3	*Cis*-5,8,11,14,17-Eicosapentaenoic acid	53.682
C24:1	Nervonic acid	54.522
C22:6n-3	*Cis*-4,7,10,13,16,19-Docosahexaenoic acid	58.740

Table S2. Gas chromatography retention time of standard amino acids

Amino acids	Retention time
Alanine	1.703
Sarcosine	1.765
Glycine	1.808
α-Aminobutyric acid	1.905
Valine	1.998
β-Aminobutyric acid	2.077
Noraline	2.120
Leucine	2.198
allo-lsoleucine	2.229
Isolucine	2.254
Threonine	2.457
Serine	2.499
Proline	2.572
Asparagine	2.656
Thioproline	2.998
Aspartic acid	3.164
Methionine	3.199
4-Hydroxyproline	3.335
Glutamic acid	3.494
Phenylalanine	3.536
α-Aminoadipic acid	3.779
α-Aminopimelic acid	4.023
Glutamine	4.105
Ornithine	4.456
Glycine-proline	4.514
Lysine	4.696
Histidine	4.879
Hydroxylysine	5.055
Tyrosine	5.141
Proline-hydroxyproline	5.342
Tryptophan	5.431
Cystathionine	5.855
Cystine	6.066