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ARTICLE

Effect of Aging Process and Time on Physicochemical and Sensory Evaluation of Raw Beef Top Round and Shank Muscles Using an Electronic Tongue

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Abstract

The objective of this study was to determine the effect of aging method (dry or wet) and time (20 d or 40 d) on physical, chemical, and sensory properties of two different muscles (top round and shank) from steers (n=12) using an electronic tongue (ET). Moisture content was not affected by muscle types and aging method (p>0.05). Shear force of dry aged beef was significantly decreased compared to that of wet aged beef. Most fatty acids of dry aged beef were significantly lower than those of wet aged beef. Dry aged shank muscles had more abundant free amino acids than top round muscles. Dry-aging process enhanced tastes such as umami and saltiness compared to wet-aging process according to ET results. Dry-aging process could enhance the instrumental tenderness and umami taste of beef. In addition, the taste of shank muscle was more affected by dry-aging process than that of round muscle.

Keywords dry-aging, muscles, meat, electronic tongue, taste

Introduction

There are many methods to quantitatively and qualitatively analyze flavor components of feeds to determine their quality, including high pressure liquid chromatography, gas chromatography, and Mass spectrometry. However, instruments for these methods require some expensive reagents. In addition, experienced operators are needed for sample preparation and instrument operating. Moreover, these methods are extremely selective. Furthermore, only limited targets can be detected (Lehotay and Hajslova, 2002; Muller and Steinhart, 2007; Nollet, 2000).

Electronic tongue is mostly used in liquid analysis using sensory arrays and pattern recognition system (Vlasov *et al*., 2002). Basically, single taste buds composed of 50 to 100 taste cells can sense five tastes such as sweetness, sourness, saltiness, bitterness, and umami (Deisingh *et al*., 2004). Harper (2001) has reported that results of sensory evaluation using an electronic sensory machine are positively correlated with results of using human sensory panelists. In case of human sensory evaluation, experiment not only needs trained sensory panelists, but also needs time for training panelists with high cost. Lyon and Lyon (2001) have indicated that human sensory evaluation can be affected by individual sensory experience.

For these reasons, Legin *et al*. (2003) have found that it is possible to use an electronic tongue to replace human sensory evaluation for wine.

Research on consumers purchasing characteristics and satisfaction for Hanwoo beef has revealed that there are differences in consumer preference depending on beef muscle types: loin, 43.5%; rib, 22.9%; tenderloin, 10.5%; brisket, 9.9%; and the sum of top round and shank, 4.7% (Hwang *et al*., 2010). Acceptability for shank and round muscles has also found to be less than that for other muscles (Jeremiah *et al*., 2003). Chemical characteristics of meat such as collagen contents, nucleotide acids, free amino acids, and fatty acid compositions are also dependent on muscle types such as chuck roll, strip loin, top round, and brisket (Cho *et al*., 2008; Guillemin *et al*., 2009; Hiner and Hankins, 1950; Lee *et al*. 2010). Most round muscles with high quality are used for steaks while some round muscles with high amounts of connective tissues are used for stew meat or ground beef similar to shank muscles which has highly tough parts (Ramsbottom and Strandine, 1947).

Meat aging technologies such as dry aging and wet aging have been utilized to improve meat quality for a long time. In wet aging, meat is aged in a vacuum-sealed pack to preserve its moisture. In dry aging, meat is dried without packing for a few weeks. Effect of dry aging on enzyme activities such as protein degradation has been determined. It has been found that dry aging contributes to intense flavor and taste of meat (Perry, 2012). Sitz *et al*. (2004) have demonstrated that some consumers prefer dry-aged meat more than wet-aged meat. In addition, they are willing to pay more for dry aged meat. Kim *et al*. (2016) have reported that drying aging process can increase the tenderness of top round muscles and consumer acceptability.

Since no study has demonstrated how wet-aging and dry-aging might affect sensory characteristics of shank and round muscles of beef during aging using an electronic tongue, the objective of this study was to determine the effect of aging method) and time on physical, chemical, and sensory properties of two muscles. This study was accomplished by proving the physicochemical, textural and sensory properties of wet-aged and dry aged beef according to different aging periods and muscles. Besides, meat sensory evaluation by using an electronic tongue can provide unique information of aging beef in useful way.

Materials and Methods

Animals and treatments

Top round and shank meats at 12 d postmortem from a total of 12 Holstein steers (age of about 26 mon) were purchased from a commercial slaughter house. Average carcass weight was 293 kg. Carcass yield grade was C according to Korean carcass grading procedure (National Livestock Cooperatives Federation, NLCF 1998). In the laboratory of Konkuk University, whole samples were cut into pieces (1.5-2.0 kg per piece). All samples (top round and shank) were randomly allocated to wet aging (top round, WTR; shank, WS) and dry aging (top round, DTR; shank, DS) groups with identical digit number for

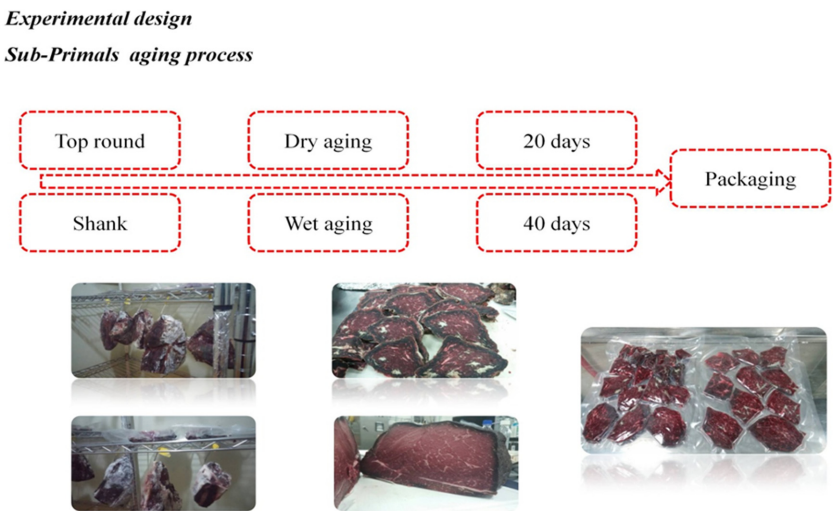

Fig. 1. Schematic illustration showing experimental design and samples.

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each group. For wet aging, muscles were aged in sealed vacuum-packed bags. For dry aging, muscles were hung in refrigerated room with air circulation system. Aging conditions in the refrigerated room were controlled at temperature of 1.0±0.5°C and relative humidity (RH) of 80-85% with air flow of 0.5-1.5 m/s. Samples were collected on day 20 and day 40 during the aging period. Experimental design and samples are shown in Fig. 1.

Analyses of physical characteristics

Moisture, crude fat, crude protein, and ash contents of samples were analyzed according to the procedure of AOAC (2002). After different aging time (20 d or 40 d), weight of each sample was compared to the initial weights. Weight loss percentage (%) was calculated using the following equation:

Weight loss (%) = {(initial weight of sample – weight after aging)/ (initial weight of sample)} × 100

Cooking loss and shear force were evaluated using published method (Kim and Lee, 2003). Briefly, steak samples (about 100 g) with thicknesses of 1.5 cm were prepared in vacuum package. These samples were cooked in a water bath at 75°C to reach internal core temperate of 70°C. They were then placed at room temperature for 30 min. Cooking loss was calculated by comparing steak weights before cooking and after cooking. To measure shear force, sample was collected from each steak parallel to muscle fiber with six replicated samples after cooling. Measurement of shear force was conducted by attaching Warner-Bratzler shear force onto an Instron universal testing machine (Instron Corporation, USA). The condition of this machine was set at cell load of 50 kg and cross-head speed of 200 mm/min.

Color measurement of all samples was conducted using a colorimeter (NR-300, Nippon Denshoku, Japan). Before measurement, all samples were placed on a bloom at room temperature for 30 min. The colorimeter was calibrated with a white plate (L*, lightness; a*, redness; b*, yellowness).

Each sample (2 g) was homogenized in 18 mL of distilled water. Homogenized sample was then subjected to pH measurement using a pH meter (pH 900, Precisa Co., Switzerland).

Fatty acid analysis

Fatty acid composition was analyzed using the method of AOAC (1995). First, lipid was extracted from sample according to method of Folch *et al*. (1957) with slightly modification. Briefly, the sample was treated with 10% boron trifluoride (BF_3) in methanol for methylation. The sample was then heated at 60°C for 40 min in a water bath. After cooling to room temperature, hexane and distilled water were added into the sample followed by centrifugation at 2,000 rpm for 15 min. The supernatant was used to analyze fatty acid compositions. Chromatography conditions were: initial oven temperature, 100°C, held for 4 min; ramping at 3°C/min to 240°C, held for 15 min. Temperatures of injector and detector were maintained at 225°C and 285°C, respectively. Flow rate of helium was set at 0.75 mL/min. Then 1 μL of solution was injected into the machine in split mode (200:1). Nonadecanoic acid methyl ester (0.3 mg/mL) was used as internal standard. It was added to each sample prior to fat extraction and methylation. The isooctane layer was dehydrated with anhydrous sodium sulfate and subjected to analysis using gas chromatography (5,890, Agilent Technologies, USA) equipped with a flame ionization detector using an SP-2560 column (100 m × 0.25 mm × 0.2 μm).

Analysis of free amino acids

Analysis of free amino acid was conducted using the method of Nishimura *et al*. (1988). Briefly, 10 g of meat was homogenized in 25 mL of distilled water for 10 min. The sample was then centrifuged at 11,500 g for 10 min at 4°C. The supernatant was filtered through a filter paper. After adding 5% trichloroacetic acid into the filtrate, the sample was centrifuged again (11,500 g for 10 min at 4°C). The supernatant was filtered with a 0.45 μm membrane filter and subjected to analysis for free amino acids using an amino acid analyzer (Jasco, Japan LC-NETII/ ADC Analyzer, Japan).

Electronic tongue analysis

Extraction of meat was conducted using published method (Escudero *et al*., 2012) with slight modification. Briefly, 5 g of meat was homogenized with 20 mL of 0.01 N HCl for 8 min using a bag mixer. The homogenized sample was centrifuged at 10,000 g for 20 min at 4°C. The extract was filtered through Whatman No. 1 (11 μm) filter paper to remove impurities such as fat and tissues. The extract was stored at -80°C until analysis. Four standard compounds ($MgSO_4$ for bitterness, HCl for sourness, NaCl for saltiness, and MSG for umami) were prepared to check the cross-selectivity of sensors. These standard

compounds were prepared at the same concentration (0.01 mol/L). Electronic tongue analysis was performed using an Electronic tongue machine (Taste sensing system SA 402B, Insent Intelligent Sensor Technology, Inc., Japan).

Statistical analysis

All treatments for this study had a split-split-plot design with three factors. The main factor was muscle type (top round and shank meats). Sub-plot treatment was aging method (wet-aging or dry-aging). Sub-sub plot was aging times (20 d or 40 d). General linear model (GLM) and Pearson correlation analyses were performed using SPSS version 18.0 (SPSS Inc., USA). Data were expressed as mean and standard error of mean. Statistical significance was considered when p-value was less than 0.05.

Results and Discussions

Proximate composition

Data on proximate compositions of top round and shank muscles are shown in Table 1. At 20 d of dry aging or wet aging, moisture contents of top round and shank muscles ranged from 68.42% to 73.80% while fat contents of both muscles ranged from 1.09% to 2.88%. Proximate compositions of top round and shank muscles were similar to those reported in a previous study (Lee *et al*., 2010) showing that ratios of moisture contents to fat content in top round and shank muscles were lower than those in higher quality grade beef. Although moisture contents of both top round and shank muscles at 20 d were not significantly (p >0.05) different between wet aged meat and dry aged meat, dry-aged meat at 40 d had lower moisture contents than wet-aged meats in both top round and shank muscles. After aging for 20 d and 40 d, protein contents of all groups were increased (p<0.05) except for those in the wet aged top round group. Protein contents of dry-aged beef were increased more than those of wet-aged beef at 40 d (p<0.001). This result could be related to the fact that the reduction ratio of moisture content in the dry-aging process was relatively higher than that in the wet-aging process. Wet aged beef had lower (p<0.05) ash content compared to dry aged beef.

Table 1. Least square means of three factors (muscle types, aging method, and aging time) on proximate compositions (%) in top round (TR) and shank muscles (SH)

	Moisture	Crude fat	Crude protein	Crude ash
Muscle type				
Top round	70.19	2.15	27.55	1.18
Shank	70.24	2.26	25.28	1.14
p-value	0.987	0.247	<0.001	0.833
SEM	2.22	0.36	0.24	0.02
Aging				
Dry	67.79	2.68	27.86	1.25
Wet	72.63	1.72	24.97	1.06
p-value	0.147	0.079	<0.001	<0.001
SEM	2.23	0.36	0.24	0.02
Muscle type and aging method				
TR[1)] and Dry	68.46	2.76	29.41	1.08
TR and Wet	72.02	1.53	25.68	1.27
SH[2)] and Dry	67.13	2.60	26.30	1.05
SH and Wet	73.24	1.91	24.26	1.23
p-value	0.692	0.599	0.024	0.810
SEM	3.11	0.50	0.33	0.03
Aging method and aging time				
Dry and 20	69.49	2.03	25.72	2.03
Dry and 40	66.10	3.34	30.00	3.34
Wet and 20	72.85	1.14	24.38	1.14
Wet and 40	72.41	2.30	25.56	2.30
p-value	0.647	0.889	<0.001	0.649
SEM	3.11	0.50	0.33	0.03

[1)]TR, top round; [2)]SH, shank muscle

Weight loss, cooking loss, pH, and shear force

Results of weight loss, cooking loss, pH, and shear force of wet and dry aged beef are shown in Table 2. The pH values of both top round and shank with dry-aging process at 40 d were significantly increased compared to those of aged beef at 20 d after dry aging. Increased pH in dry-aged beef has been observed (Obuz *et al*., 2014). Increasing pH in beef through the aging process can be occurred by the formation of nitrogen compounds from proteolysis (Aksu *et al*., 2005). However, the pH of wet aged beef was decreased (p<0.05) from 20 d to 40 d. The pH value of shank was higher than that of top round regardless of aging time or aging method. According to Lee *et al*. (2010), pH values of various muscles are different. Aging method and aging time showed significant (p<0.001) interaction effect on pH of meat. Wet aged beef showed lower pH value than dry-aged beef at both 20 d and 40 d (p<0.05). The decrease in pH of meat with vacuum package during aging might have contributed to accumulation of lactic acid originated from meat born lactic acid bacteria (Blixt and Borch, 2002). The increase in pH of meat during dry-aging process could be due to the formation of nitrogen compounds from proteins caused by proteolysis (Aksu *et al*., 2005). Aging process can influence pH and water-holding capacity of meat (Boakye and Mittal, 1993).

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Table 2. Least square means of three factors (muscle types, aging method, and aging time) on pH, shear force, cooking loss, and weigh loss of top round and shank muscles

	pH	Shear force (kg)	Cooking loss (%)	Weight loss (%)
Muscle type				
Top round	5.55	5.31	20.58	10.90
Shank	6.01	5.59	18.69	11.84
p-value	<0.001	0.333	0.131	0.187
SEM	0.01	0.20	0.83	0.49
Aging				
Dry	6.24	5.14	12.91	19.18
Wet	5.37	5.76	26.36	3.56
p-value	<0.001	0.033	<0.001	<0.001
SEM	0.01	0.20	0.81	0.47
Muscle type and aging method				
TR[1)] and Dry	5.84	5.47	14.88	17.65
TR and Wet	5.27	5.70	26.28	4.15
SH[2)] and Dry	6.65	4.80	10.94	20.71
SH and Wet	5.46	5.82	26.44	2.98
p-value	<0.001	0.168	0.104	0.006
SEM	0.02	0.31	1.04	0.68
Aging method and aging time				
Dry and 20	6.11	6.55	13.61	12.91
Dry and 40	6.38	3.72	12.20	25.45
Wet and 20	5.62	5.46	27.66	1.88
Wet and 40	5.12	6.05	25.06	5.25
p-value	<0.001	<0.001	0.620	<0.001
SEM	0.02	0.30	1.08	0.70

[1)]TR, top round; [2)]SH, shank muscle

Oiao *et al*. (2001) have explained that pH of meat has positive correlation with water holding capacity and expressible drip while water-holding capacity has negative correlation with moisture content.

Cooking loss of dry-aged muscles was significantly ($p<0.001$) lower than that of wet-aged muscles. However, there was no significant ($p>0.05$) difference in cooking loss between top round and shank. The decrease in cooking loss of dry-aged muscles might be due to less moisture content caused by evaporation (Juárez *et al*., 2011). Similarly, Obuz *et al*. (2014) have reported that wet-aged loin steak has higher cooking loss than dry-aged loin steak.

Weight loss of both muscles treated with dry-aging process was significantly higher than that of wet aged muscles at 20 d and 40 d. The ratio of weight loss in both muscles treated with wet and dry aging constituted to increase ($p<0.001$) during aging. In addition, aging method and muscle type showed significant ($p<0.001$) interaction effect on weight loss of beef. Although weight loss of wet aged shank showed lower tendency than that of wet-aged top round, the shank muscle treated with dry aging process showed higher weight loss compared to top round treated with dry aging.

No significant difference in shear force was found between muscle types, although the shear force of dry aged meat was lower ($p<0.05$) compared to that of wet aged meat. Aging method and aging time showed significant ($p<0.001$) effect on shear force. Dry aging process decreased shear force as expected. Although there was numerically difference of the shear force between 20 d and 40 d, the significant difference of shear force in wet-aged beef was not detected ($p>0.05$). However, wet aging process did not decrease the shear force at 40 d. According to previous studies, both shear force and tenderness with aged flavor in beef loin improved with increasing the aging time from 14 d to 49 d (Lepper-Blilie *et al*., 2016) in agreement with Obuz *et al*. (2014) who demonstrated shear force is decreased with increasing aging time. Campbell *et al*. (2001) have indicated that dry aging process can improve sensory characteristics and decrease shear force after 14 d and 21 d.

Color

Muscle type did not affect L* (lightness), a* (redness), or b* (yellowness). An interaction between muscle type and aging method was not found for color values (Fig. 2). Lightness and yellowness values of dry aged beef were decreased compared to those of wet aged beefs. Lightness and yellowness values of aged beef at 20 d were higher ($p<0.05$) than those of wet aged beef. The redness value of aged beef was increased ($p<0.05$) during aging. Qioa *et al*. (2001) have reported correlations of lightness with pH (r=-0.9632), moisture (r=0.6633), and water-holding capacity (r=-0.8929). Therefore, the low lightness value in dry aged beef observed in the present study might be due to high pH and higher water-holding capacity of meat. Although aging method did not influence redness of meat, aging time did affect the redness value. Redness of shank muscle of wet aged beef was slightly but significantly ($p<0.05$) increased during aging. Similar result has been reported by Ismail *et al*. (2008) showing that aging time has effect on the color of ground beef. Color stability can be different according to muscle type since each muscle had different oxygen consumption rate and metmyoglobin reductase activity (Madhavi and Carpenter, 1993).

Free amino acids

Results of free amino acids (FAA) analysis for different

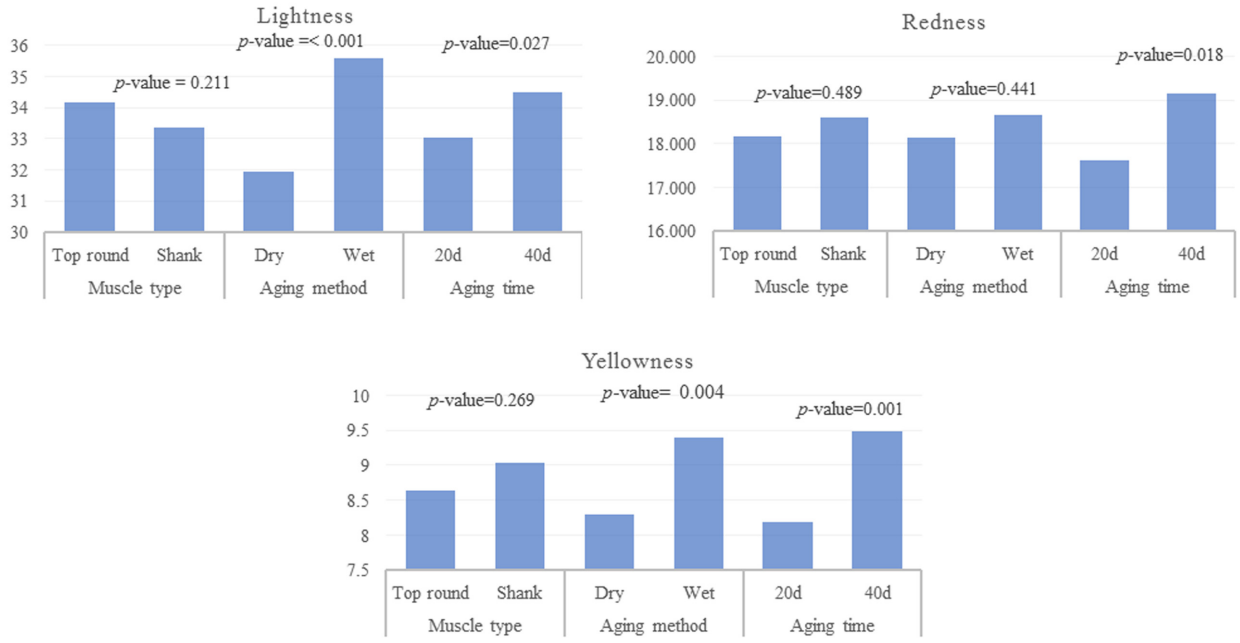

Fig. 2. Values of lightness, redness and yellowness according to three factors (treatment, aging method, and aging time) of different muscles.

muscles treated with wet or dry aging process are shown in Table 3. Contents of most free amino acids were significantly (p<0.001) increased in both wet aged and dry aged beef after aging. Contents eof total free amino acids (TFA) and some free amino acids such as Asp and Glu related to umami taste in shank muscles (SH) were higher (p<0.001) than those in top round muscles (TR). Moreover, muscle type and aging method showed significant (p<0.001) effect on contents of TFA, Asp, and Glu. Shank muscle were influenced by aging more than top round muscle. Glutamic acid and aspartic acid could enhance the umami taste of meat. Contents of both Glu and Asp in dry aged beef were higher (p<0.001) than those in wet aged beef. Approximately 6-fold of increase (p<0.001) of glutamate content was found for wet aged beef after aging. Aging method and aging time showed significant (p<0.001) effect on glutamate content. Dry aging process resulted in lower glutamate content compared to the wet aging process. This might be due to moisture removal in the dry aging process since glutamate is a water-soluble component of umami taste (Sasaki *et al*., 2007). As expected, TFA content was increased (p<0.001) with increasing aging time. However, TFA content in dry aged muscle was lower (p<0.05) than that in wet aged muscle, similar to results of a previous report (Feidt *et al*., 1996) showing a positive relationship between FAA content and protein degradation in meat with increasing aging time. Therefore, the increase in free amino acids after aging might be due to proteolysis of muscles during the ageing process.

Fatty acid

Results of fatty acid compositions of wet and dry aged beefs (top round and shank muscles) are shown in Table 4. It is known that fatty acid compositions in meat are associated with sensory flavor profiles (Wood *et al*., 2003). Fatty acid compositions were not affected by muscle types (p>0.05). However, compositions of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA) of wet aged beef were higher (p<0.05) than those of dry aged beef. Recommended ratio of PUFA to SFA (P:S) is 0.4 (Wood *et al*., 2003). The SFA (P:S) of beef after the dry aging process was more close to the recommended P:S ratio compared to that after the wet aging process. Dry aged beef had lower (p<0.05) C18: 3n3, which 3n3 has negative effect on flavor when C18 3n3 reacts with volatile compounds from the cooking process, than wet aged beef (Campo *et al*., 2003). Aging method and aging time showed significant (p<0.05) interaction effect on C18:3n3. This result might be due to the decrease of C18:3n3 during the dry aging process. MUFA (C14:1 and C16:1) at 20 d were lower compared to those

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Table 3. Free amino acids contents of top round and shank muscles with three factors (muscle type, aging method, and aging time)

mg/kg	Muscle type			Aging methods			Aging time (d)			*p*-value	
	Top round	Shank	*p*-value	Dry	Wet	*p*-value	20	40	*p*-value	MT*AM[1)]	AM*AT[2)]
Asp	225.67	793.67	<0.001	527.49	491.85	<0.001	263.54	755.80	<0.001	<0.001	<0.001
Glu	2462.12	4247.87	<0.001	3574.64	3135.34	<0.001	2938.23	3771.76	<0.001	<0.001	<0.001
Asn	410.80	175.44	<0.001	112.73	473.50	<0.001	249.74	336.49	<0.001	<0.001	0.032
Ser	1109.44	1020.65	0.014	1050.42	1079.67	0.332	1132.90	997.19	0.001	0.005	0.011
Gln	1629.52	771.27	<0.001	330.84	2069.94	<0.001	576.62	1824.17	<0.001	0.549	<0.001
His	671.32	1017.81	<0.001	1023.63	665.50	<0.001	791.75	897.38	0.021	0.010	0.167
Gly	990.96	1305.97	<0.001	1106.07	1190.86	<0.001	1070.43	1226.51	<0.001	<0.001	<0.001
Thr	1110.73	1415.99	<0.001	1317.49	1209.23	0.007	1187.90	1338.83	0.001	0.487	0.058
Arg	147.42	67.59	<0.001	58.74	156.26	<0.001	147.84	67.16	<0.001	<0.001	<0.001
Ala	3755.60	5075.63	<0.001	4702.66	4128.57	<0.001	4200.47	4630.76	<0.001	0.008	<0.001
Tau	9900.95	10535.96	0.05	10943.19	9493.73	<0.001	9995.35	10441.57	0.027	0.053	0.059
GABA	243.83	453.24	<0.001	329.71	367.37	0.100	489.56	207.52	<0.001	0.020	0.385
Tyr	348.52	195.85	<0.001	362.87	181.50	<0.001	168.10	376.27	<0.001	0.560	<0.001
Val	1528.90	1952.47	<0.001	1797.72	1683.64	0.003	1645.84	1835.53	<0.001	0.007	0.005
Met	960.55	1065.74	<0.001	1035.74	990.55	0.047	980.54	1045.75	0.010	0.248	0.259
Try	202.24	236.26	0.034	305.65	132.85	<0.001	249.80	188.71	0.002	0.003	0.007
Phe	1406.49	1422.54	0.680	1335.25	1493.77	0.003	1442.50	1386.52	0.174	0.520	0.021
Iso	1186.17	1414.23	<0.001	1319.51	1280.90	0.198	1282.39	1318.01	0.990	0.011	0.314
Leu	2222.27	2424.62	0.005	2321.24	2325.64	0.934	2323.77	2323.12	<0.001	0.084	0.017
Lys	998.14	843.28	<0.001	987.36	854.07	0.001	802.87	1038.56	<0.001	0.171	<0.001
Pro	547.15	1185.28	<0.001	1091.34	641.09	<0.001	707.76	1024.67	<0.001	<0.001	0.002
TFA	32058.79	37621.36	<0.001	35598.66	34081.49	0.018	32647.88	37032.28	<0.001	0.060	0.962

[1)]MT, Muscle type; [2)]AM, Aging method; [3)]AT, Aging time; [4)]TFA, Total free amino acid

Table 4. Fatty acids compositions of top round and shank muscles with three factors (muscle type, aging method, and aging time)

mg/g	Muscle type			Aging method			Aging time (d)			*p*-value	
	Top round	Shank	*p*-value	Dry	Wet	*p*-value	20 d	40 d	*p*-value	MT[1)]*AM[2)]	AM*AT[3)]
C10	0.08	0.06	0.133	0.06	0.08	0.482	0.07	0.07	0.996	0.966	0.614
C12	0.11	0.08	0.287	0.06	0.13	0.051	0.08	0.11	0.227	0.446	0.781
C14	2.66	2.31	0.627	1.31	3.66	0.009	2.36	2.61	0.732	0.959	0.955
C16	30.08	28.15	0.762	18.69	39.54	0.010	28.10	30.13	0.750	0.785	0.642
C17	0.95	0.70	0.265	0.57	1.08	0.042	0.65	1.00	0.134	0.275	0.716
C18	16.14	10.07	0.149	8.64	17.57	0.047	9.42	16.78	0.089	0.201	0.607
C20	0.11	0.07	0.212	0.06	0.12	0.051	0.07	0.11	0.263	0.357	0.653
C24	0.10	0.10	0.887	0.10	0.10	0.797	0.09	0.11	0.203	0.744	0.430
SFA	50.23	41.53	0.439	29.50	62.26	0.015	40.84	50.92	0.026	0.725	0.936
C14:1	0.76	1.46	0.042	0.62	1.59	0.010	1.62	0.59	0.007	0.005	0.054
C16:1	4.59	8.00	0.061	4.00	8.55	0.019	8.68	3.87	0.015	0.008	0.084
C18:1n9	51.62	65.09	0.307	38.91	77.80	0.014	63.79	52.93	0.405	0.146	0.196
C20:1	0.35	0.50	0.158	0.31	0.55	0.032	0.51	0.35	0.118	0.051	0.311
C22:1n9	0.04	0.03	0.687	0.03	0.04	0.376	0.03	0.04	0.457	0.856	0.923
MUFA	57.87	75.65	0.252	44.22	89.30	0.014	75.19	58.33	0.028	0.100	0.176
C18:2n6	5.38	5.23	0.707	4.73	5.88	0.016	4.88	5.74	0.052	0.142	0.083
C18:3n3	0.12	0.11	0.654	0.10	0.13	0.026	0.11	0.13	0.140	0.870	0.022
C20:2	0.15	0.12	0.016	0.14	0.14	0.991	0.12	0.16	0.004	0.248	0.007
C20:3n6	0.80	0.75	0.264	0.78	0.77	0.819	0.69	0.85	0.005	0.425	0.022
C20:4n6	2.07	2.53	0.019	2.18	2.42	0.179	2.27	2.33	0.744	0.242	0.693
C20:3n3	0.03	0.04	0.548	0.04	0.03	0.835	0.03	0.04	0.463	0.140	0.652
PUFA	8.55	8.78	0.677	7.96	9.37	0.032	8.10	9.24	0.069	0.501	0.103
SFA/PUFA	0.22	0.29	0.101	0.30	0.20	0.025	0.27	0.24	0.465	0.283	0.310

[1)]MT, Muscle type; [2)]AM, Aging method; [3)]AT, Aging time

at 40 d (p<0.05). However, some PUFA (C20:2 and C20:3n6) were increased (p<0.05) after aging. Muscle types and aging method had significant (p<0.001) interaction effect on contents of C14:1 and C16:1. Madhavi and Carpenter (1993) reported that each muscle had different oxygen consumption and enzyme activities. Therefore, these high MUFAs in meat might be related with stearoyl-CoA desaturase activity (St.John *et al*., 1991).

Electronic tongue

Results of electronic tongue analysis for aged beef are summarized in Table 5. Aged top round muscle showed significantly lower taste values compared to aged shank muscle except for bitterness. Dry-aged beef had lower sourness but higher bitterness, astringency, umami, and saltiness than wet-aged beef (p<0.001). Most tastes of aged beef might be affected by compositions of free amino acids (Watanabe *et al*., 2016). The sourness of wet-aged beefs could be affected by accumulated lactic acid under anaerobic condition (Warren and Kastner, 1992). Taste enhancement of meat after the aging process is affected by free amino acids and nucleotides such as glutamate and aspartate affecting the umami taste (Liu *et al*., 2007). Umami compounds of beef are increased with aging time, with dry-aged beef having higher umami score compared to wet-aged beef (Li *et al*., 2014). Kawai, Okiyama, and Ueda (2002) have suggested that a combination of glutamate and 5'-nucleotides can enhance the umami taste of foods. Especially, umami taste can improve the flavor of meat (Lindemann, 2000; Maga, 1998).

Conclusions

Physicochemical, texture, and sensory properties of top round and shank muscles are affected by aging methods (dry and wet) and aging time (20 d and 40 d). Shank muscles were more affected by the dry-aging process compared to top round muscles. Results of electronic tongue analysis showed that umami and saltiness tastes of muscles were enhanced by the dry-aging process. In addition, the aging process improved the taste of shank muscles. Instrumental tenderness of dry-aged beef regardless of

Table 5. Sensory evaluation for top round and shank muscles with three factors (muscle type, aging method, and aging time) based on electronic tongue analysis

	Sourness	Bitter	Astrin	After-b	After-a	Umami	Rich	Saltiness
				Muscle type				
Top round	-19.91	5.14	-2.39	-0.72	-0.23	8.96	0.79	-8.37
Shank	-21.65	5.56	-2.11	-0.36	-0.17	9.51	1.14	-7.66
p-value	0.045	0.052	0.004	<0.001	<0.001	0.072	<0.001	<0.001
SEM	0.52	0.13	0.05	0.02	0.01	0.19	0.02	0.08
				Aging method				
Dry	-25.81	6.95	-1.92	-0.54	-0.16	10.73	0.95	-7.61
Wet	-15.75	3.75	-2.58	-0.55	-0.24	7.73	0.98	-8.42
p-value	<0.001	<0.001	<0.001	0.769	<0.001	<0.001	0.398	<0.001
SEM	0.52	0.13	0.05	0.02	0.01	0.19	0.02	0.08
				MT and AM				
TR and Dry	-23.23	6.29	-2.10	-0.68	-0.19	9.99	0.79	-7.98
TR and Wet	-16.59	4.00	-2.68	-0.76	-0.27	7.93	0.80	-8.76
SH and Dry	-28.39	7.61	-1.74	-0.40	-0.12	11.48	1.12	-7.25
SH and Wet	-14.91	3.51	-2.48	-0.33	-0.22	7.53	1.17	-8.08
p-value	0.002	0.001	0.304	0.030	0.156	0.007	0.528	0.816
SEM	0.73	0.18	0.07	0.03	0.01	0.26	0.03	0.11
				AM and AT				
Dry and 20	-20.83	4.79	-2.18	-0.38	-0.20	9.41	1.30	-7.85
Dry and 40	-30.79	9.11	-1.66	-0.70	-0.11	12.06	0.60	-7.38
Wet and 20	-15.20	3.46	-2.66	-0.36	-0.24	7.67	1.26	-8.47
Wet and 40	-16.30	4.05	-.2.50	-0.73	-0.25	7.80	0.71	-8.36
p-value	<0.001	<0.001	0.031	0.390	<0.001	0.001	0.051	0.135
SEM	0.73	0.18	0.07	0.03	0.01	0.26	0.03	0.11

MT, Muscle type; AM, Aging method; AT, Aging time; TR, top round; SH, shank muscle; Bitterness, Bitter; Astrin, Astringency After-b is aftertaste of bitterness; After-a is aftertaste of astringency; Rich is aftertaste of umami.

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muscle types was improved through aging time. However, the effect of aging on other flavor compounds such as fatty acids and nucleotides using ET and electronic nose for sensory evaluation needs to be determined in further studies. Comparison of different muscles treated with wet and dry-aging methods will provide information to control for aging time.

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