African Journal of Biotechnology Vol. 10(37), pp. 7253-7259, 20 July, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.096
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Distinct physicochemical characteristics of different beef from *Qinchuan* cattle carcass

Lin-Qiang Li[1] and Lin-Sen Zan[2,3]*

[1]College of Food Engineering and Nutritional Science, Shaanxi Normal University, Xi'an, Shaanxi 710062, China.
[2]College of Animal Science and Technology, Northwest A&F University, Yangling, Shaanxi 712100, China.
[3] National Beef Cattle Improvement Centre, Yangling, Shaanxi 712100, China.

Accepted 11 April, 2011

A total of 30 Qinchuan cattle were used to investigate the physicochemical characteristics of beef from three different parts of cattle carcass, namely longissimus dorsi (LD), serratus ventralis (SV) and semitendinosus (ST). Multiple parameters were ranked in the descending order of ST > SV > LD, and include muscle pH, protein, ash, drip loss, cooking loss, shear force and hydroxyproline (Hyp). In contrast, water, fat, lightness (L*) and redness (a*) was in the opposite order. C18:1 and C16:0 were the main intramuscular fatty acids (FA), and C19 - C22 were undetectable. The saturated fatty acids (SFA) content were ranked in the descending order of LD > SV > ST, whereas unsaturated fatty acids (UFA) were the opposite. The essential amino acid (EAA) content were ranked in the descending order of ST > SV ≥ LD. No significant differences in the contents of mineral elements were observed in LD, SV and ST. The ranking patterns were similar in both males and females. Taken together, these results revealed significant differences in physicochemical properties of LD, SV and ST, except the mineral elements.

Key words: Cattle, Qinchuan breed, carcass, different beef, physicochemical characteristics.

INTRODUCTION

As one of the five best cattle breeds in China, Qinchuan cattle are classified as a national resource conservation breed. They graze on the Guanzhong Plain (also called "Qinchuan", hence the name) in Shaanxi province. Qinchuan cattle are known to produce tender, high-grade beef, with rich flavor and high nutritional value. At present, Qinchuan beef is highly in-demand both at home and abroad, including Hong Kong, Macao, Russia and South Korea. Recently, with increasing focus on meat quality, research on Qinchuan beef quality has significantly had impact on the production process. Beef quality is affected by many factors, such as age (Prost et al., 1975; Shackelford., 1995), sex (Prost et al., 1975; Choat et al., 2006), nutritional status (Aberle et al., 1981; Bidner et al., 1981, 1986), postmortem aging (Vieira et al., 2006; Monsón et al., 2005), different positions (Pauline et al., 1970) and so on.

Despite extensive research on Qinchuan beef quality in recent years (Li et al., 2009; Zhang et al., 2009) few studies have examined the meat quality characteristics of different Qinchuan cattle parts. The objective of this study was to investigate the physicochemical characteristics of beef from different parts of Qinchuan cattle, which may enhance our understanding of meat quality and promote healthy consumption of beef.

*Corresponding author. E-mail: zanls@yahoo.com.cn. Tel:+86-29-87092468; Fax: +86-29-87092468.

Abbreviations: **LD,** Longissimus dorsi; **SV,** serratus ventralis; **ST,** semitendinosus; **Hyp,** hydroxyproline; **L*,** lightness; **a*,** redness; **b*,** yellowness; **FA,** fatty acid; **SFA,** saturated fatty acid; **UFA,** unsaturated fatty acid; **PUFA,** polyunsaturated fatty acid; **EAA,** essential amino acid

MATERIALS AND METHODS

Samples collection

Twenty (20) males and ten (10) females of the same Qinchuan cattle breed, born within a 30-day period and of similar genetic background, were used in this study. When they were about 18 months old, the animals were divided into three groups: ten intact males (IM); ten castrated males (CM); and ten females (FM). The animals were raised under the same experimental conditions and fed the same diets at 4 to 5 kg/day (48.78% corn, 20.43% bran, 26% corn grit, 1.97% cotton cake, 2.3% vitamin and mineral supplement and 0.5% salt) for a fattening period of six months. After the next 12 days after slaughtering, the carcasses were stored at 2°C. Meat samples were obtained from the center of LD, SV and ST of carcass. Each analysis was conducted in duplicate.

Meat quality evaluation

The pH was measured at the same position using a Thermo Orion pH meter (C310P- 43, Orion, USA). Water content was measured by weight loss after drying at 100°C for 24 h (AOAC, 1984). Crude protein content was determined by the Kjeldahl procedure (AOAC, 1984), using the Tecator Kjeltec System (Tecator, Hoganas, Sweden). Crude fat content was evaluated by extracting with petroleum ether (boiling point: 30 to 60 °C) in a Soxhlet extractor for 8 h, and the ash content by ashing at 600°C for 8 h (AOAC, 1984). Meat color (L*, a* and b*) were determined using a WSC-S colorimeter (Shanghai Precision and Scientific instrument CO., LTD. Shanghai, China). Drip loss were calculated on a steak weighing about 80 g and 1.5 cm thick and kept for 48 h in a plastic container with a double bottom (Lundstrom and Malmfors, 1985). Cooking loss were measured on a 4 cm-thick steak, sealed in a polyethylene bag and heated in a water bath to an internal temperature of 70°C (Destefanis et al., 2003). Fresh muscle samples were cut into small blocks (10 × 10 cm) and cooked in separate plastic bags in a water-bath at 80°C for 60 min. From each cooked meat block, samples (1 × 1 cm) were prepared and shear force was measured by Texture Analyzer (TA-XT2i, British Stable Micro System Company) (Neath et al., 2007). Hyp content was determined according to the international organization for standardization (ISO) (1978). The GC-MS analysis of fat was conducted by using an Agilent GC/MS equipped with a HP-5MS capillary column (30 m × 0.25 mm, 0.25 μm film thickness). Heating programs: heating from 70 to 200°C at a rate of 5°C•min^{-1}, lasting for 3 min, with the He carrier gas at a flow rate of 1mL•min^{-1} in the split mode (1:50). The mass spectrometer was operating (full scan-mode) in the EI-mode at 70 eV. The ion source temperature was 230°C. Amino acid content was measured according to the AOAC (1984), using Beckman 121 (Beckman Instrument, USA). Microelements content was determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES, Perkin-Elmer, USA). Muscle fiber was evaluated by the routine haematoxylin and eosin staining of paraffin sections. Sarcolemma was evaluated by environmental scanning electron microscopy (Quanta 200, FEI CO., Holland). The data were analyzed by one way ANOVA (SPSS 13.0, 2004). Differences between two groups were evaluated using a post-hoc test.

RESULTS

Physicochemical characteristics of beef from different parts of carcass

Results from detailed physiochemical analysis of different beef are shown in Table 1, and changes in LD, SV and ST muscle fiber during postmortem aging are shown in Figures 1 and 2, respectively. Specifically, muscle pH was ranked in the following descending order: ST > SV > LD; the same order was observed in several other parameters including protein, ash, drip loss, cooking loss, shear force, and Hyp. In contrast, water, fat, L* (lightness), and a* (redness) exhibited the opposite order. There were no significant differences in b* (yellowness) among ST, SV, and LD (p > 0.05). This ranking patterns were largely the same in males and females. The LD muscle fiber underwent significant changes after aging, with significantly increased muscle fiber gap and fragmentation of muscle fiber. SV also exhibited significant change, whereas ST was largely unaffected, devoid of muscle fiber fragmentation. The sarcolemma of LD, SV and ST muscle fiber were distinct, yet did not exhibit significantly changes after aging. These results together indicated that the physicochemical properties of LD, SV and ST were significantly different.

FA composition of different beef

The fatty acid compositions for LD, SV and ST are shown in Table 2. C18:1 and C16:0 were the main intramuscular fatty acids in different beef. The contents of other fatty acids were relatively low, and C19 - C22 were not detectable. The SFA content were ranked in the descending order of LD > SV > ST, whereas that of UFA was the opposite. These results showed that the intramuscular fatty acids composition structure was roughly similar in different muscle types of males and females, and polyunsaturated fatty acids (PUFA) content was extremely low. Taken together, these observations indicated that crude fat content negatively correlated with nutritional value.

Essential amino acid (EAA) in different beef

The EAA composition of LD, SV and ST are shown in Table 3. Leu and Lys contents were relatively high, as compared to those of the remaining EAA. The EAA content were ranked in the descending order of ST > SV ≥ LD, either for males or females. The observed similar composition of EAA in different beef, coupled with the earlier mentioned crude protein analysis, indicated that crude protein content positively correlated with nutritional value.

Mineral content of different beef

The mineral elements in LD, SV and ST are shown in Table 4. K was the most abundant, followed by Na and Mg; the remaining elements were relatively low. There was no significant difference in the mineral content among LD, SV and ST of males and females. It is possible that the mineral content may be mainly affected by diets.

DISCUSSION

Physicochemical characteristics of meat are known to closely correlate with its nutritional and commercial value,

Table 1. Physicochemical characteristics of beef from different parts of carcass.

Parameter	Intact male (n = 10)			Castrated male (n = 10)			Female (n = 10)		
	LD	SV	ST	LD	SV	ST	LD	SV	ST
pH	4.92±0.12[a]	5.43±0.32[b]	5.82±0.13[c]	4.84±0.11[a]	5.25±0.33[b]	5.75±0.28[c]	4.74±0.14[a]	5.34±0.34[b]	5.73±0.13[c]
Water (g/100 g)	75.31±0.44[a]	74.91±0.63[a]	72.82±0.93[b]	74.72±0.64[a]	73.24±0.81[a]	71.11±0.44[b]	74.24±0.43[a]	73.04±0.73[a]	71.54±0.81[b]
Protein (g/100 g)	18.93±0.64[a]	19.03±1.63[a]	21.74±0.81[b]	17.72±0.43[a]	18.04±0.83[a]	22.94±0.62[b]	17.11±0.63[a]	18.32±1.14[a]	23.33±0.33[b]
Fat (g/100 g)	5.73±0.44[a]	4.82±0.33[b]	3.63±0.64[c]	6.44±0.61[a]	4.83±0.42[b]	3.91±0.52[c]	7.13±0.91[a]	5.93±0.33[b]	4.14±0.61[c]
Ash (g/100 g)	1.62±0.33[a]	1.61±0.43[a]	1.84±0.21[b]	1.51±0.43[a]	1.54±0.42[a]	1.78±0.31[b]	1.53±0.22[a]	1.62±0.24[a]	1.73±0.31[b]
L*	48.40±0.41[a]	46.82±0.73[b]	36.81±0.63[c]	48.64±0.60[a]	47.20±0.32[ab]	37.43±0.72[c]	48.94±0.33[a]	47.53±061[b]	38.34±0.91[c]
a*	28.43±0.71[a]	26.82±0.93[b]	23.42±0.53[c]	29.30±0.91[a]	26.23±0.74[b]	24.13±0.80[c]	29.81±0.72[a]	26.83±0.84[b]	25.14±0.51[c]
b*	24.44±0.71[a]	25.41±0.72[a]	26.43±0.92[a]	24.34±0.84[a]	25.61±0.83[a]	25.22±0.63[a]	24.04±0.61[a]	25.33±0.72[a]	26.24±0.83[a]
Drip loss (g/100 g)	2.44±0.23[a]	2.93±0.51[ab]	5.44±0.32[c]	2.23±0.51[a]	2.93±0.54[ab]	5.34±0.71[c]	2.14±0.61[a]	2.92±0.43[ab]	5.04±0.44[c]
Cooking loss (g/100 g)	30.34±0.53[a]	30.91±0.62[ab]	35.43±0.73[c]	28.23±0.61[a]	30.14±0.33[b]	33.34±0.53[c]	27.41±0.44[a]	29.82±0.83[b]	31.94±0.51[c]
Shear force (N)	45.33±8.41[a]	50.90±7.81[b]	110.91±9.92[c]	44.83±9.51[a]	46.91±7.33[a]	103.21±9.22[b]	42.32±8.33[a]	44.64±8.82[a]	99.53±7.92[b]
Hyp (mg/100 g)	0.84±0.051[a]	0.94±0.043[b]	2..93±0.052[c]	0.72±0.063[a]	0.84±0.033[b]	2..43±0.044[c]	0.53±0.061[a]	0.73±0.051[b]	2..13±0.032[c]

Means ± SE. Means with different superscript letters (a, b and c) within the same rows indicate significant differences (P < 0.05). LD**,** Longissimus dorsi; SV, serratus ventralis; ST, semitendinosus

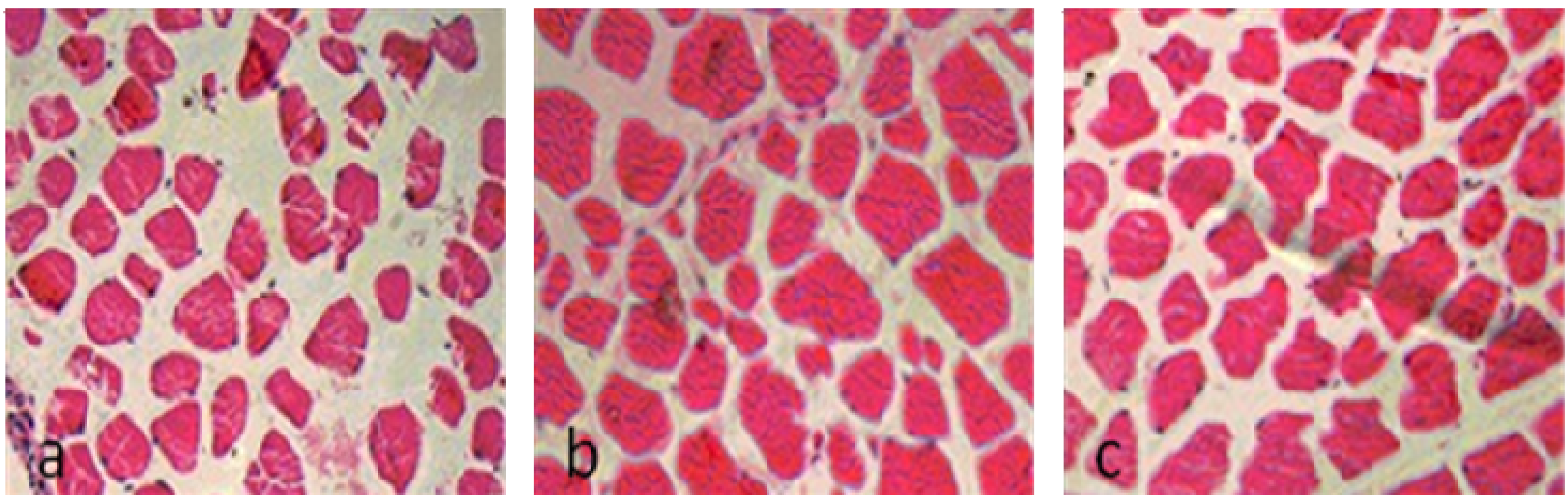

Figure 1. Paraffin sections of muscle fiber (×200) prepared from different parts of carcass after postmortem aging. a, LD; b, SV; c, ST.

Table 2. Comparison of FA composition of intramuscular fat in beef from different parts of Qinchuan cattle carcass (%).

Fatty acid	Intact male (n = 10)			Castrated male (n = 10)			Female (n = 10)		
	LD	SV	ST	LD	SV	ST	LD	SV	ST
C14:0	3.62±0.073[a]	3.13±0.81[b]	1.92±0.53[c]	4.84±0.63[a]	3.63±0.64[b]	2.44±0.31[c]	5.12±0.40[a]	5.42±0.53[a]	2.94±0.33[b]
C16:0	30.63±2.61[a]	27.92±1.92[b]	23.60±0.93[c]	34.64±1.91[a]	32.33±2.12[b]	25.41±2.54[c]	39.04±1.13[a]	36.04±1.72[b]	24.21±1.93[c]
C16:1	4.34±1.61[a]	5.31±0.62[b]	6.93±0.31[c]	3.91±1.03[a]	4.63±0.61[b]	6.04±0.62[c]	2.84±0.33[a]	4.32±0.91[b]	6.34±0.62[c]
C18:0	14.32±3.61[a]	13.82±2.32[b]	10.12±1.31[c]	13.41±1.54[a]	12.54±1.83[b]	11.83±2.72[b]	15.50±2.31[a]	13.73±2.21[b]	10.92±1.94[c]
C18:1	45.91±1.32[a]	47.34±2.33[b]	52.34±0.13[c]	40.14±1.12[a]	45.43±1.21[b]	52.24±1.94[c]	35.53±2.22[a]	36.63±1.71[a]	49.33±2.14[b]
C18:2	2.22±0.51[a]	2.93±2.71[a]	4.23±1.03[b]	2.72±0.81[a]	2.32±0.23[b]	4.72±0.31[c]	3.51±0.83[a]	4.13±0.44[b]	6.72±0.81[c]
SFA	48.57	44.87	35.64	52.89	48.50	39.68	59.66	55.19	38.07
UFA	52.47	58.58	63.50	45.77	52.38	63.00	41.88	45.08	62.39

Means ± SE. Means with different superscript letters (a, b and c) within the same rows indicate significant differences ($P < 0.05$).

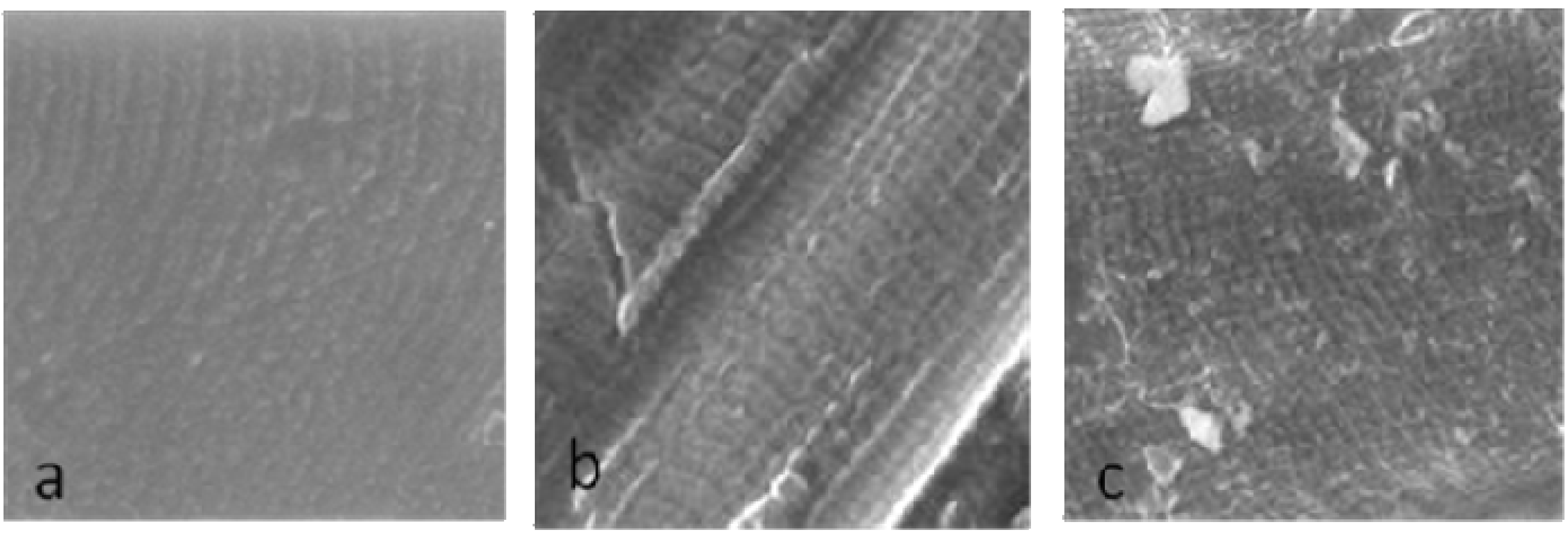

Figure 2. Electron microscopy of muscle fiber sarcolemma (×2000) prepared from different parts of carcass. a, LD; b, SV; c, ST.

especially tenderness and marbling. Tenderness is one of the important sensory properties and indicators of meat quality (Shackelford, 2001; Goodson et al., 2002). Abundant intramuscular fat tissue in beef renders a marble-like feature and enhances meat juice and sensory tenderness (Woodward et al., 1999; Indurain et al., 2006; Moon et al; 2006); thus, marbling is regarded as an important criterion for beef quality grading in

Table 3. Comparison of EAA composition in beef from different parts of Qinchuan cattle carcass (%).

AA	Intact male (n = 10)			Castrated male (n = 10)			Female (n = 10)		
	LD	SV	ST	LD	SV	ST	LD	SV	ST
Thr	1.01±0.022[a]	1.16±0.041[b]	1.25±0.12[b]	0.94±0.12[a]	1.03±0.12[a]	1.14±0.042[b]	0.88±0.13[a]	0.90±0.043[a]	1.02±0.023[b]
Val	1.03±0.11[a]	1.07±0.11[a]	1.13±0.14[b]	0.92±0.12[a]	0.96±0.12[a]	1.11±0.13[b]	0.86±0.12[a]	0.89±0.081[a]	0.98±0.011[b]
Met	0.72±0.13[a]	0.85±0.11[a]	0.86±0.11[b]	0.73±0.12[a]	0.79±0.14[a]	0.83±0.11[b]	0.71±0.13[a]	0.76±0.12[b]	0.78±0.021[c]
Ileu	1.14±0.11[a]	1.16±0.12[a]	1.23±0.14[b]	1.08±0.11[a]	1.13±0.14[b]	1.19±0.11[b]	1.02±0.23[a]	1.08±0.041[b]	1.14±0.043[c]
Leu	1.71±0.13[a]	1.83±0.11b	1.93±0.15[b]	1.64±0.23a	1.72±0.17[b]	1.82±0.12[c]	1.59±0.23[a]	1.63±0.072[b]	1.72±0.051[c]
Tyr	0.81±0.23[a]	0.84±0.12[a]	0.85±0.11[a]	0.79±0.12[a]	0.81±0.13[a]	0.85±0.11[b]	0.72±0.14[a]	0.80±0.031[b]	0.82±0.014[b]
Phe	0.84±0.24[a]	0.93±0.11[b]	1.04±0.21[c]	0.78±0.16[a]	0.84±0.11[b]	0.96±0.17[c]	0.76±0.11[a]	0.81±0.044[b]	0.88±0.032[c]
Lys	1.92±0.13[a]	2.14±0.10[b]	2.13±0.15[b]	1.76±0.13[a]	1.97±0.12[b]	2.02±0.11[b]	1.69±0.12[a]	1.85±0.13[b]	2.04±0.052[c]

Means ± SE. Means with different superscript letters (a, b and c) within the same rows indicate significant differences (P < 0.05).

Table 4. Comparison of mineral content in beef from different parts of Qinchuan cattle carcass (mg/kg).

Element	Intact male (n = 10)			Castrated male (n = 10)			Female (n = 10)		
	LD	SV	ST	LD	SV	ST	LD	SV	ST
Mg	217.82±15.63	281.03±75.51	239.52±26.43	217.82±15.63	281.04±75.52	249.53±6.44	217.83±5.62	281.02±75.52	219.53±6.42
Cu	2.33±0.54	1.94±0.62	2.13±0.22	2.34±0.91	2.91±0.83	2.14±0.22	2.32±0.53	2.91±0.61	2.10±0.50
Zn	34.03±1.72	34.44±1.72	33.53±0.14	33.91±3.84	32.03±0.41	33.52±0.62	34.03±3.74	34.42±2.73	33.52±2.13
Mn	0.22±0.032	0.23±0.14	0.23±0.021	0.32±0.093	0.54±0.032	0.34±0.092	0.34±0.033	0.32±0.12	0.32±0.083
Ca	17.42±9.72	16.83±7.42	17.51±3.62	18.53±2.81	19.32±0.83	18.53±3.62	17.42±7.73	18.82±7.42	19.52±3.64
Fe	23.74±6.042	34.62±11.63	32.20±11.23	23.14±0.71	18.63±1.53	32.22±1.23	33.74±6.04	24.60±3.61	32.24±9.22
Na	436.03±63.04	459.53±93.23	795.91±99.62	444.52±8.93	564.53±18.04	485.94±59.62	406.03±63.02	435.53±23.23	460.92±39.62
K	5700.03±367.02	5567.02±316.03	5450.02±212.01	5093.63±94.02	5083.62±114.93	5050.02±212.03	5400.03±367.02	5367.04±216.83	5550.03±312.01

Japan (JMGA, 1998; Yoshikaw et al., 2000), US (USDA, 1987), South Korea (Kim and Lee, 2003; APGS, 1995), China and so on. In this study, we examined several beef types and analyzed multiple parameters related to tenderness and marbling abundance, such as drip loss, cooking loss, shear force, contents of water, intramuscular fat and Hyp. Our detailed physicochemical analyses revealed the order of LD > SV > ST, which is concordant with their relative commercial value. Significant changes in muscle fiber micro-structure were observed among LD, SV and ST after aging, indicating distinct tenderness improvement. The tenderness and the content of intramuscular fat were analysed on the same three parts of Japanese wagyu, namely LD, SV and ST. The results were as following: (i) Shear force of LD, SV, and ST: 28, 34 and 42 N, respectively; (ii) the content of intramuscular fat of LD, SV and ST: 28, 17 and 9 g/100 g. It suggested that the physico-chemical characteristics of Japanese wagyu were ranked in the descending order of LD > SV > ST, which is similar to that of Qinchuan cattle, and the physicochemical characteristics of Japanese wagyu are superior to that of Qinchuan cattle on commercial value.

Consistent with observations in previous studies (Seideman et al., 1982; Monin, 1990; Klont et al., 1998), our results suggested that pH may be responsible for meat color. It is conceivable that glycogen fuels lactate production and thus decreases the pH; therefore, muscle glycogen concentration at the time of slaughter is an important factor affecting beef quality (Immone et al., 2000).

Intramuscular fatty acid composition in beef has been extensively studied. Consumption of saturated fatty acids (SFA) has been shown to increase the content of serum cholesterol and low-density lipid protein (LDL) (Enser et al., 1998), and accelerate atherosclerosis, leading to coronary heart disease (CHD). In contrast, PUFA, in particularly n-3 series PUFA, appeared to reduce the risk of CHD (Chen et al., 2007; Ulbricht and Southgate, 1991). This study showed low levels of PUFA in beef, in concordance with previous literature (Cameron et al., 1994). It has been recommended that SFA in food should be no more than 10% of the total energy and it is necessary to minimize the myristic acid (C14:0) and palmitic acid (C16:0) content (Prasad et al., 1991). Therefore, despite excellent taste and high price beef with rich marbling may carry adverse nutritional consequences. According to the intramuscular fat content and FA composition analyses, the FA nutritional value were ranked in the descending order of ST > SV > LD, which is contrary to their commercial value. The contents of PUFA of Japanese wagyu were analysed on the same three parts of Japanese wagyu, and the results of LD, SV and ST were 0.4, 0.7, and 1.0 g/100 g, respectively, suggesting the same order of the their FA nutritional value as compared to that of Qinchuan cattle, but lower than that of Qinchuan cattle.

This study showed EAA and microelements contents in LD, SV and ST, suggesting that crude and ash content positively correlated with nutritional value, which is consistent with our results on the same parts of Japanese wagyu, but the contents of EAA and microelements were lower than that of Qinchuan cattle. In conclusion, there are significant differences in physicochemical properties of LD, SV and ST, except mineral elements.

ACKNOWLEDGEMENTS

We would like to thank all the investigators, research assistants and laboratory technicians who contributed to this study. This work was supported by The Changjiang Scholars and Innovative Research Team Support Plan of The Ministry of Education (No. IRt 0940), and the Sci-Tech Innovation Project of Shaanxi Province 13115 (No. 2010 ZDGC-01).

REFERENCES

Aberle ED, Reeves ES, Judge MD, Hunsley RE, Perry TW (1981). Payability and muscle characteristics of cattle with controlled weight gain: time on a high energy diet. J. Anim. Sci., 52: 757-763.

AOAC (1984). Official Methods of Analysis (14th Ed.). Washington, DC: Association of Official Analytical Chemist.

APGS (1995). Report of business for animal products grading. Animal Products Grading System. Seoul, Korea: National Livestock Cooperatives Federation.

Bidner TD, Schupp AR, Montgomery RE, Carpenter Jr. JC (1981). Acceptability of beef finished on all-forage, forage-plus-grain or high energy diets. J. Anim Sci., 53: 1181-1187.

Bidner TD, Schupp AR, Mohamad AB, Rumore NC, Montgomery RE, Bagley CP, McMillin KW (1986). Acceptability of beef from Angus-Hereford or Angus-Hereford-Brahman steers finished on all-forage or a high energy diet. J. Anim Sci., 62: 381-387.

Cameron PJ, Zembayashi M, Lunt DK, Mitsuhashi T, Mitsumoto M, Ozawa S, Smith SB (1994). Relationship between Japanese beef marbling standard and intramuscular lipid in the M. longissimus thoracis of Japanese Black and American Wagyu Cattle. Meat. Sci., 38: 361-364.

Choat WT, Paterson JA, Rainey BM, King MC, Smith GC, Belk KE, Lipsey RJ (2006). The effects of cattle sex on carcass characteristics and longissimus muscle palatability. J. Anim. Sci., 84: 1820-1826.

Chen YJ, Zhou GH, Zhu XD, Xu XL, Tang XY, Gao F (2007). Effect of low dose gamma irradiation on beef quality and fatty acid composition of beef intramuscular lipid. Meat. Sci., 73: 423-431.

Destefanis G, Brugiapaglia A, Barge MT, Lazzaroni C (2003). Effect of castration on meat quality in Piemontese cattle. Meat. Sci., 64: 215-218.

Enser M, Hallett KG, Hewett B, Fursey FAJ, Wood JD, Harrington G (1998). Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implication for human nutrition. Meat. Sci., 49: 329-341.

Goodson KJ, Morgan WW, Reagan JO, Gwartney BL, Courington S, Wise JW, Savell JW (2002). Beef customer satisfaction: Factors affecting consumer evaluations of clod steaks. J. Anim. Sci., 80: 401-408.

Immone K, Ruusunen M, Hissa K, Puolanne E (2000). Bovine muscle glycogen concentration in relation to finishing diet, slaughter and ultimate pH. Meat. Sci., 55: 25-31.

Indurain G, Beriain MJ, Goni MV, Arana A, Purroy A (2006). Composition and estimation of intramuscular and subcutaneous fatty acid composition in Spanish young bulls. Meat. Sci., 73: 326-334.

International Organisation for Standardisation (1978). Meat and meat products, part II, determination of L(-) hydroxyproline content. ISO, 3496.

JMGA (1998). New beef carcass grading standards.Tokyo: Japan Meat Grading Association.

Kim CJ, Lee ES (2003). Effects of quality grade on the chemical,physical and sensory characteristics of Hanwoo (Korean native cattle) beef. Meat. Sci., 63: 397-405.

Klont R E, Brocks L, Eikelenboom G (1998). Muscle fibre type and meat quality. Meat Sci , 49 (Supplement 1): 219-229.

Li LQ, Zan LS,Zhang BX (2009). Influence of ultrasound-assisted calcium chloride marination treatment on beef tenderness. J. Transa. CSAE, 25(6): 290-295 (in Chinese).

Lundström K, Malmfors G (1985). Variation in light scattering and water holding capacity along the porcine longissimus dorsi muscle. Meat. Sci. 15: 203-215.

Monsón F, Sañudo C, Sierra I (2005). Influence of breed and ageing time on the sensory meat quality and consumer acceptability in intensively reared beef. Meat. Sci., 71: 471-479.

Moon SS, Yang HS, Park GB, Joo ST. (2006). The relationship of physiological maturity and marbling judged according to Korean grading system to meat quality traits of Hanwoo beef females. Meat. Sci., 74: 516-521.

Monin C (1990). Facteurs biologiques et qualités de la viande. In: R.G. Guilhermet and Y. Geay, Editors, Croissance des bovins et qualité de la viande. ENSA. Rennes, pp. 177-196.

Neath KE, Del Barrio AN, Lapitan RM, Herrera JRV, Cruz LC, Fujihara T, Muroya S, Chikuni K, Hirabayashi M, Kanai Y (2007). Difference in tenderness and pH decline between water buffalo meat and beef during postmortem aging. Meat. Sci., 75: 499-505.

Pauline C, Mandigo RW, Arthaud VH (1970). Textural and histologic difference among 3 muscles in the same cut of beef. J. Food Sci., 35: 505-510.

Prasad US, Walker WS, Sang CTM, Campanella C, Cameron EWJ (1991). Influence of obesity on the early and long term results of surgery for coronary artery disease. Eur. J. Cardio-Thorac., 5: 67-73.

Prost E, Pelczynska E, Kotula AW (1975). Quality characteristics of bovine meat. I. Content of connective tissue in relation to individual

muscles, age and sex of animals and carcass quality grade. J. Anim Sci., 41: 534-540.
Prost E, Pleczynska E, Kotula AW (1975). Quality characteristics of bovine meat. II. Beef tenderness in relation to individual muscles,age and sex of animals and careass and carcass quality grade. J. Anim Sci., 41: 541-547.
Shackelford SD, Koohmaraie M, Wheeler TL (1995). Effects of slaughter age on meat tenderness and USDA carcass maturity scores of beef females. J. Anim. Sci., 73: 3304–3309.
Shackelford SD, Wheeler TL, Meade MK, Reagan JO, Byrnes BL, Koohmaraie M (2001). Consumer impressions of tender select beef. J. Anim Sci., 79: 2605-2614.
Seideman SC, Cross HR, Oltjen RR, Schanbacher BD (1982). Utilization of the intact male for red meat production: A review. J. Anim. Sci., 55: 826-840.
USDA (1987). Official United States Standards for Grades of Carcass Beef.
Ulbricht TL, Southgate DAT (1991). Coronary heart disease: seven dietary factors. Lancet, 338: 985-992.
Vieira C, García-Cachán MD , Recio MD, Domínguez M, Sanudo C (2006). Effect of ageing time on beef quality of rustic type and rustic x Charolais crossbreed cattle slaughtered at the same finishing grade. Span. J. Agric. Res., 4: 225-234.
Woodward BW, Fernández MI (1999). Comparison of conventional and organic beef production systems II. Carcass characteristics. Livest. Prod. Sci., 61: 225-231.
Yoshikawa F, Toraichi K, Wada K, Ostu N, Nakai H, Mitsumoto M, Katagishi K (2000). On a grading system for beef marbling. Pattern Recogn Lett., 21: 1037-1050.
Zhang BX, Zan LS,Li LX,Men JW (2009). Studies on the tenderization effects of lactic acid on Qin-chuan beef at different ages. J. Northwest A&F Univ., 37(3): 30-35 (in Chinese).