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Full Length Research Paper

Effect of sex on meat quality characteristics of *Qinchuan* cattle

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A total of 18 Qinchuan cattle, six intact males (IM), six castrated males (CM) and six females (FM), were used to investigate the effect of sex on the physicochemical characteristics (PCC) and fatty acid (FA) composition of the *Longissimus dorsi* muscle (LDM). Obvious sex differences were found in the PCC of LDM: the IM group had higher shear value, pH, drip and cooking losses, and contents of ash and hydroxyproline (Hyp) than the CM and FM groups, as well as lower ether extract content and lightness. Both the IM and CM groups had lower water content and higher protein content than the FM group. Sex differences were also observed in contents of C14:0, C14:1, C18:1, saturated fatty acids (SFA), mono-unsaturated fatty acids (MUFA) and unsaturated fatty acids (UFA) between the IM and both the CM and FM groups but not between the CM and FM groups. The results indicated that sex is an important source of differences in meat quality of Qinchuan cattle because the castration and the meat characteristics of the CM group were more similar to the FM than the IM group.

Key words: Qinchuan breed, sex, physicochemical characteristics, fatty acid composition.

INTRODUCTION

Qinchuan cattle are a Chinese native yellow breed which is ranked as one of the best livestock breeds and has been promoted across the country by the Ministry of Agriculture in China (Fu and Liu, 2005). Because of its high nutritional value, high protein content, high ratio of meat to bone in the carcass, low fat content, large loin eye area and good eating quality, the Qinchuan breed should be as good as foreign beef breeds such as Charolais or Limousin on the basis of some meat quality traits (Qiu, 1995; Qiu et al., 1997). However, Qinchuan cattle tend to have lower carcass fat content and intramuscular adipose tissue deposition. This influences meat quality and consumer acceptability and is a key factor constraining the entry of Qinchuan cattle into the market for top-grade beef.

The hormonal status of beef cattle is related to meat quality characteristics such as tenderness and fat and protein distribution (Fritsche and Steinhart, 1998). Sex has been recognized as one of the ante mortem factors contributing to variation in beef muscle characteristics because it affects muscle and fat depositions in the carcass (Choat et al., 2006; Guillemin et al., 2009; Panjono et al., 2009). Steers and heifers produce more tender meat (Peachey et al., 2002; Purchas et al., 2002), more intramuscular fat, higher marbling score and quality grade of carcass (Choi et al., 2002; Frickh et al., 2003; Lazzaroni and Biagini, 2008; Litwinczuk et al., 2006; Panjono et al., 2009; Schreurs et al., 2008), better meat quality parameters and sensory traits (Frickh et al., 2003; Velik et al., 2008) than bulls, while heifers have greater tenderness (Bass et al., 2010) and better sensory traits and marbling scores than steers (Frickh et al., 2003; McIntyre et al., 2009). Studies have also shown that the beef physicochemical properties, especially WHC, were affected by sex and heifer meat had significantly more dry matter and fat than meat from young bulls irrespective of breed

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Abbreviations: IM, Intact males; **CM,** castrated males; **FM,** females; **PCC,** physicochemical characteristics; **FA,** fatty acid; **LDM,** *Longissimus dorsi* muscle; **Hyp,** hydroxyproline; **SFA,** saturated fatty acids; **MUFA,** mono-unsaturated fatty acids; **UFA,** unsaturated fatty acids.

(Litwinczuk et al., 2006), whereas the mean fiber cross-sectional area and percentage of fast glycolytic fibers were greater in bulls than steers (Schreurs et al., 2008).

It was concluded that sex affects muscle and fat deposits in the carcass (Panjono et al., 2009) and consequently affects meat quality characteristics such as tenderness, muscle fibre characteristics, etc. (Nielsen and Thamsborg, 2005). However, few studies have been conducted on the effects of sex on meat quality characteristics in Qinchuan cattle. The objective of this study was to investigate the effect of sex on the physico-chemical characteristics (PCC) of meat and the FA composition of intramuscular fat from Qinchuan cattle of different sexes to reveal any effects of sex on meat quality characteristics and provide the basis for further study on the mechanism by which sex influences meat quality.

MATERIALS AND METHODS

Animal samples

Twelve male Qinchuan cattle and six females of the same breed, born within a 30-day period and of similar genetic background, were used in this study. The animals were equally divided into three groups (six intact males, IM; six castrated males, CM; six females, FM) when they were about 30 months old, and were raised under the same experimental conditions and fed the same diets consisting of concentrate at 4 - 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. The CM cattle were castrated by means of Burdizzo emasculator at the age of 12 months. The weights at the start of fattening were 559 ± 7.58 kg for the IM group, 476 ± 4.83 kg for the CM group and 408 ± 8.05 kg for the FM group. When the cattle were slaughtered, their average age was 35.8 ± 0.2 months, and the final average weights were 650 ± 10.43, 548 ± 4.89 and 466 ± 9.82 kg for IM, CM and FM, respectively. The mean daily gains were 0.93 ± 0.04 kg for the IM group, 0.69 ± 0.05 kg for the CM group and 0.60 ± 0.02 kg for the FM group. According to commercial standard procedures, the animals were stunned by a captive bolt and then slaughtered. Over the following 12 days, the carcasses were aged at 2°C.

Meat quality evaluation

Two days after slaughter the pH was measured at same position in the LDM on the right side using a Thermo Orion pH meter (C310P-43, Orion, USA). Twelve days after slaughter a portion of steak from the LDM between the 8th and 12th ribs was taken from the right side of each animal. After aging, these samples were kept at 2°C throughout the following analyses, each conducted in duplicate. 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). The ether extractable content was evaluated by extracting with petroleum ether for 8 h, and the ash content by ashing at 600°C for 8 h (AOAC, 1984). Lightness, Chroma and Hue were determined using a WSC-S colorimeter (Shanghai Precision and Scientific instrument CO., LTD. Shanghai, China) (Zhou and Xu, 1990). Drip losses 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 (Lundström and Malmfors, 1985). Cooking losses 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). Shear values were determined on cylindrical cores 2.54 cm in diameter, taken parallel to the muscle fibers and obtained from the steaks used to determine cooking losses; the shear force was measured using an C-LM3 digital display tenderness instrument equipped with a shearing device (XIELI Sci. CO., LTD. Harbin, China) and calibrated at 100 mm/min (Zhou and Xu, 1990). Hydroxyproline (Hyp) content was determined according to the International Organization for Standardization [ISO] (1978). Separated fat content was evaluated by esterification using KOH-CH_3OH solution and individual FAs were identified and quantified with a GC663-30 gas chromatograph (Hitachi) and flame ionization detectors fitted with a 2 m × 3 mm capillary column; the apparatus was programmed with an initial temperature of 150°C for 4 min, allowing increases of 1 - 3°C /min up to a final temperature of 195°C. The temperature of the injector and detector was 250°C. Hydrogen was used as the carrier gas (30 ml/min). The system did not allow for the identification of *cis/trans* isomers. The data were analyzed by one way ANOVA (SPSS 13.0, 2004). Differences between two groups were compared using a post-hoc test.

RESULTS

The analysis results are shown in Tables 1 and 2. The IM group contained significantly more water than the CM and FM groups ($p < 0.01$) while the CM and FM groups had greater ether extractable contents than the IM group ($p < 0.01$). Both the IM and CM groups had higher protein content than the FM group ($p < 0.05$), while the FM group had lower ash content than the IM and CM groups ($p < 0.05$). The IM group had lower tenderness and higher Hyp content than the CM and FM groups ($p < 0.05$). The differences of Hyp content between the FM group and the IM group were highly significant ($p < 0.01$). The IM group had higher muscle pH than the CM and FM groups ($p < 0.05$). Both the CM and FM groups produced lighter meat than the IM group ($p < 0.05$), while the IM group produced tougher meat than the others ($p < 0.05$). The IM group also had lower drip losses and cooking losses than the CM and FM groups ($p < 0.05$). Sex differences also had effects on the FA composition of the intramuscular fat. Compared with the CM group, the IM group differed significantly in C14:0, C14:1, C18:1, SFA, MUFA and UFA ($p < 0.05$), and it also differed significantly from the FM group in C14:0, C18:1, MUFA and UFA ($p < 0.05$). There were no significant differences between the CM and FM groups in the FA composition of the intramuscular fat.

DISCUSSION

The results in Table 1 show that sex affected the chemical composition of the muscle: the fat content was higher and the water content lower in the CM and FM groups. These findings are in agreement with Monin and Ouali (1991), Frickh et al. (2003) and Lazzaroni and Biagini (2008). Destefanis et al. (2003) observed that castration induced higher fat deposition and a lower water content in the

Table 1. Chemical and physical characteristics of Qinchuan cattle meat.

Parameter	Intact males (n=6)	Castrated males (n=6)	Females (n=6)
Water (g/100g)	74.69±0.54^{A}	71.92±0.62^{B}	71.30±0.18^{B}
Protein (g/100g)	23.88±0.51^{a}	22.99±0.54^{a}	22.39±0.26^{b}
Ether extract (g/100g)	1.89±0.15^{B}	4.15±0.60^{A}	4.00±0.48^{A}
Ash content (g/100g)	1.89±0.16^{a}	1.83±0.23^{a}	1.18±0.18^{b}
Hydroxyproline (mg/g)	0.77±0.03^{aA}	0.66±0.03^{bAB}	0.57±0.04^{bB}
Shear force values (kg)	5.27±0.34^{a}	4.01±0.40^{b}	3.73±0.33^{b}
pH	5.52±0.12^{a}	4.63±0.37^{b}	4.54±0.15^{b}
Lightness	27.48±0.97^{b}	30.94±1.38^{a}	30.98±1.03^{a}
Chroma	23.17±0.47	22.03±0.45	21.51±0.74
Hue	15.19±0.30	15.71±0.52	15.91±0.44
Drip losses (%)	2.58±0.16^{a}	1.79±0.24^{b}	1.87±0.19^{b}
Cooking losses (%)	32.21±0.66^{a}	29.24±0.98^{b}	28.64±0.98^{b}

Means ± SE. Means with different superscript letters (a, b; A, B) within the same rows differ significantly (P<0.05; P<0.01).

Table 2. Comparison of fatty acid compositions of intramuscular fat from Qinchuan cattle of different genders (%)

Fatty acid	Intact males (n=6)	Castrated males (n=6)	Females (n=6)
C14:0	3.67±0.25^{aA}	2.55±0.31^{bB}	2.02±0.19^{bB}
C14:1	0.26±0.02^{a}	0.20±0.01^{b}	0.23±0.02^{ab}
C14:2	0.19±0.02	0.18±0.03	0.18±0.03
C15:0	0.26±0.03	0.24±0.03	0.26±0.01
C15:1	0.55±0.01	0.24±0.03	0.21±0.03
C15:2	0.17±0.01	0.13±0.02	0.13±0.01
C16:0	32.48±1.07	31.39±0.83	31.96±1.26
C16:1	4.04±0.40	3.71±0.17	3.98±0.38
C16:2	0.69±0.06	0.67±0.04	0.58±0.04
C17:0	0.29±0.02	0.28±0.01	0.28±0.01
C17:1	0.38±0.16	0.53±0.17	0.82±0.23
C18:0	10.43±0.59	9.07±0.69	10.04±0.59
C18:1	44.67±0.69^{bB}	48.21±1.07^{aAB}	49.58±1.03^{aA}
C18:2	0.87±0.13	0.72±0.16	0.73±0.02
SFA	47.14±0.97^{a}	43.52±0.96^{b}	44.52±0.83^{ab}
MUFA	49.9±0.93^{bB}	53.48±0.88^{aAB}	54.27±1.08^{aA}
PUFA	1.93±0.04	1.70±0.21	1.62±0.02
UFA	51.83±0.92^{bB}	55.09±0.86^{aAB}	55.97±1.07^{aA}
PUFA/SFA	0.041±0.001	0.039±0.005	0.036±0.004

Means ± SE. Means with different superscript letters (a, b; A, B) within the same rows differ significantly (P<0.05; P<0.01).

muscle, and Litwinczuk et al. (2006) reported that meat from heifers had significantly higher fat content ($p < 0.001$) than from bulls, similar to our results. Moreover, the IM group had higher protein content than the CM and FM groups ($p < 0.05$). The IM group showed greater muscle development and less fat deposition than the CM group, which was mainly attributed to the effects of masculine hormones (particularly testosterone) on muscle protein anabolism (Morgan et al., 1993); the opposite was observed in the CM and FM groups because of thyroid insufficiency and a consequent slowdown of oxidative processes (Aguggini et al., 2000). In fact, treatment of the animals with an androgenic hormone (trenbolone acetate) was effective in reducing fat deposition and increasing muscle mass, and converse effects were observed when animals were treated with diethylstilbestrol (DES) (Williams et al., 1975; Couse et al., 1987). Goodpaster and Kelley (1998) and Stumvoll et al. (2000) alleged that intramuscular

fat metabolism is subject to hormonal regulation. Different endocrine environments could cause changes in fat and muscle tissue metabolism.

Hyp is an essential ingredient of collagen in connective tissue, and its content reflects the collagen content and is closely related to tenderness (Jeremiah et al., 2003). Toughness of meat is partly the result of collagen cross-linking in connective tissues from striated muscle, leading to rubber-like characteristics (Lepetit, 2007, 2008). A higher Hyp content in bulls was reported by Boccard et al. (1979) and Gerrard et al. (1987) and was ascribed to the anabolic effects of testosterone on collagen synthesis. Furthermore, McCormick (1994) found that a reduction in collagen turnover decreases its solubility, and intramuscular collagen was more soluble in bulls than castrates. In the present study we found lower Hyp contents in the CM and FM groups, which may be due chiefly to the lack a testosterone effect. As the animals in the CM group were castrated at the age of 12 months, that is, late castration, they had been subject to some of the anabolic effects of testosterone on collagen synthesis. Lower collagen contents in early (0.37) than in late (0.44) castrated animals were reported for Piemontese cattle (Destefanis et al., 2003). Qinchuan cattle tend to produce more Hyp than Piemontese cattle, which may partly result from later ages. In addition, we found more collagen in the CM than the FM group in this study, but the difference was insignificant ($p > 0.05$).

The IM and CM groups had significantly higher ash contents than the FM group ($p < 0.05$), which may closely reflect the different capacities for protein and fat deposition in the three groups. A significant positive relationship between protein and ash ($r = 0.68$) and the opposite relationship between ether extractable material and ash ($r = -0.62$) were reported in beef by Covington et al. (1970), indicating that the lower ash content in the FM group was related to their lower protein content and higher ether extractable content than the other groups.

Tenderness is the most important determinant of eating quality for consumers (Chandraratne et al., 2006; Park et al., 2001; Tian et al., 2005). Sex is an important intrinsic source of differences in beef tenderness (Alves et al., 2005). In our study, the shear force values showed a gradually descending tendency in the three groups, ranging from 5.27 to 3.73; the IM group had lower tenderness than the CM and FM groups ($p < 0.05$), but the tenderness difference between the CM and FM groups was not statistically significant (Table 1). Many studies have shown that steers and heifers produce more tender meat than bulls (Seideman et al., 1982; Dikeman et al., 1986; Peachey et al., 2002) and heifers are more tender than steers (Bass et al., 2010), but other studies have been unable to detect significant differences in tenderness in the meat from bulls, steers and heifers (Gracia et al., 1970; Frickh et al., 2003; Litwinczuk et al., 2006). There are many conflicting reports concerning differences in tenderness of meat from carcasses of bulls, steers and heifers, probably because tenderness is a very complex and multifactorial sensory meat quality trait that is very variable according to animal type (age, breed, sex), rearing conditions (Guillemin et al., 2009) and postmortem tenderization caused by degradation of the myofibrillar proteins involved in scaffolding of the muscle structure (Koohmaraie, 1995, 1996). Intramuscular fat also contributes indirectly to the tenderness of beef by causing remodeling of intramuscular connective tissue structures and reducing their mech-anical strength. In most cases, meat from heifers and steers was more tender and had better sensory properties than meat from bulls.

With respect to color of meat, some studies have reported that IM tend to produce darker meat (Seideman et al., 1982; Monin and Ouali, 1991), similar to our study. Monin (1990) pointed out that a higher pH may be responsible for the darker color of bull meat, because of their excitable temperament and consequently more rapid antemortem glycolysis. Glycogen fuels postmortem lactate production and thus decreases the pH, so muscle glycogen concentration at the time of slaughter is one of the most important factors affecting beef quality (Immone et al., 2000). Since the factor most likely to deplete muscle glycogen is stress, animals with excitable temperaments tend to produce darker meat with higher pH. In addition, several reports have demonstrated that sex affects the water holding capacity of beef, and lower cooking losses have been observed in steers and heifers (Dikeman et al., 1986; Riley et al., 1983; Litwinczuk et al., 2006). These results were consistent with ours. It has been shown that cooking loss is positively related to collagen content, particularly thermally stable collagen content (Bailey, 1985; Okeudo and Moss, 2005). The lower observed values in the CM and FM groups may be attributed to the lack of a stimulating effect of testosterone on collagen synthesis (Gerrard et al., 1987).

The FA composition also plays an important role in the eating quality of meat (Laborde et al., 2001). In the present study, the FA composition of intramuscular fat in Qinchuan cattle showed higher C18:1 and lower C18:2 contents than other breeds regardless of gender, which may be related to the amount of linoleic acid in the diet, since relatively more dietary linoleic acid than other fatty acids is incorporated into adipose tissue and muscle. Another probable reason is that the proportion of linoleic acid declines in muscle as fat deposition increases because the content of phospholipids, where linoleic acid is located, declines as a proportion of muscle lipid, while the proportion of neutral lipid, with its higher content of saturated and monounsaturated fatty acids, increases (Wood et al., 2008). Moreover, since Qinchuan cattle tend to produce less intramuscular fat, it is expected that the PUFA content of the fat will be higher. However, this was not observed in our study. A possible reason for the lower PUFA content of the fat from Qinchuan cattle may be that the finishing diet comprised mainly grain; the finishing

diet strongly influences the fatty acid composition of beef (Smith et al., 2009). Zea et al. (2007) reported that saturated fatty acids (SFA) were higher in animals fed with concentrates, while animals fed with silage had higher levels of PUFA and higher PUFA/SFA ratios. Furthermore, Smith et al. (2009) reported that grain feeding stimulates the activity of adipose tissue stearoyl-CoA desaturase in marbling adipose tissue and depresses ruminal isomerization/hydrogenation of dietary PUFA, resulting in a marked increase in MUFA in beef over time.

Sex was also a major influence on the FA composition of lipids in intramuscular fat deposits (Westerling et al., 1979). In this study, there were significant differences in C14:0, C14:1, C18:1, SFA, MUFA and UFA between the IM and the CM or FM groups but not between the CM and the FM groups. This is consistent with the report of Westerling et al., (1979) on steers and heifers, but not with other reports on sex differences in the contents of C18:1, C14:0, C14:1, C16:1 and MUFA (Waldman et al., 1968; Zembayashi et al., 1995). Breed variation may be a major reason for the apparent inconsistency. Other potentially important sources of variation cannot be ignored, such as the different dietary compositions, environmental and breeding conditions used in experiments. In addition, our results showed that the UFA content tended to be higher in the CM and FM groups than the IM group, and the reverse was true for SFA content. This indicates that the CM and FM groups were more capable of intramuscular fat deposition than the IM group as a result of increasing UFA synthesis. That may be associated with hormonal differences and their possible influence on enzymatic systems, since lipid metabolism in the adipose tissue can be changed by manipulating the sex hormone status of cattle (Prior et al., 1983). However, the cellular and molecular mechanisms underlying the effects of sex on fatty acid composition, especially in ruminants, are not fully understood.

In conclusion, the effects of sex on meat quality were studied in 18 Qinchuan cattle (6 IM, 6 CM and 6 FM) from the same herd and slaughtered at about 36 months old. The sex of the animal had an obvious effect on the physicochemical characteristics of the meat, especially on water content, pH, lightness, tenderness, intramuscular fat deposition and Hyp content. Sex also greatly influenced the differences in FA composition in the intramuscular fat from Qinchuan cattle. As a Chinese native beef breed, Qinchuan cattle present some unique FA composition properties, especially the high C18:1, low C18:2 and low PUFA. Clarifying the molecular mechanism responsible for the effects of sex on meat quality would be an important step in further studies.

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