Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages

D. Bureš, L. Bartoň

Cattle Breeding Department, Institute of Animal Science, Prague-Uhříněves, Czech Republic

ABSTRACT: The effects of sex and slaughter age on growth, feed intake, carcass composition and meat quality attributes of *musculus longissimus lumborum* were investigated in Charolais × Simmental bulls (n = 12) and heifers (n = 12) reared and finished under identical management conditions. The animals entered the experiment at similar age (251 days) and were slaughtered at 14 or 18 months of age. Bulls gained more rapidly ($P < 0.001$), consumed more dry matter daily ($P < 0.05$), and had a higher killing-out proportion ($P < 0.05$). The sex × slaughter age interaction was significant ($P < 0.01$) for feed conversion ratio, which deteriorated markedly more in heifers than in bulls as slaughter age increased. Bulls produced leaner carcasses with a higher proportion of total meat ($P < 0.001$). While bulls contributed to high-priced meat by a higher proportion of meat from the shoulder ($P < 0.01$), heifers had higher proportions of meat from the rump and loin ($P < 0.05$). Older animals were generally fatter and their carcasses contained lower proportions of high-priced meat ($P < 0.01$) and bones ($P < 0.05$). Bulls exhibited lower contents of dry matter ($P < 0.001$), protein ($P < 0.05$) and intramuscular fat ($P < 0.001$), and a higher content of collagen ($P < 0.001$) in *musculus longissimus lumborum* than hei-fers. The meat from heifers was assessed by the sensory panel as more tender and, when aged for 11 days, more acceptable than the meat from bulls. Older animals obtained higher scores for beef flavour intensity ($P < 0.01$), tenderness ($P < 0.001$), juiciness ($P < 0.05$), and overall acceptance ($P < 0.001$).

Keywords: beef cattle; sex; slaughter age; growth; carcass composition; meat quality

Weight gains, feed efficiency and carcass quality are of great economic importance to cattle producers. Variations in these production traits can be attributed to differences in genetic composition, nutrition, slaughter endpoints and sex (e.g. Mandell et al., 1997a; Albertí et al., 2008). Several reports have been published that compare feedlot and carcass characteristics of bulls and heifers finished under various feeding conditions and slaughtered at different live weights (Steen, 1995; Steinwidder et al., 2002). It appears that bulls and heifers of the same breed entering the finishing period at the same age and fed the same diet need different times to reach the optimum endpoint. The results of such comparisons are, however, limited in the literature.

Current consumers' behaviour is still more influenced by information concerning the origin, appearance, nutritional value, health impacts, and sensory characteristics of food. For beef, in price scarcely competing with the meat of other farm animals (especially pork and chicken), high eating quality is of special importance. In comparison with the meat from other species, beef has been shown to obtain high scores for odour and flavour intensity but low tenderness scores (Rødbotten et al., 2004).

Meat quality, including sensory characteristics of beef, is affected by a number of factors, such as breed (Chambaz et al., 2003), nutrition (Bartoň et al., 2010), ante-mortem treatment of animals (Jeleníková et al., 2008), post-mortem treatment and ageing of meat (Campo et al., 1999; Monsón et al., 2005), and cooking methods (Panea et al., 2008). Several authors have also examined sex differences

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in meat quality between bulls and steers (Cross et al., 1984a; Mandell et al., 1997a). While only minor differences in meat quality between crossbred bulls and heifers had been observed in a study by Hoving-Bolink et al. (1999), significant effects were reported by Velik et al. (2008). Moreover, direct comparisons of eating quality of beef from bulls and heifers slaughtered at a fixed age are scarce in the literature.

The objective of this study was to determine the effects of sex, age at slaughter and possible interactions of the two factors on growth, feed intake, carcass composition and meat quality attributes of Charolais × Simmental bulls and heifers produced under similar management conditions. An intensive feeding strategy was applied to enable the crosses to fully express their growth potential.

MATERIAL AND METHODS

Animals, diet and experimental design

Twelve bulls and twelve heifers used in this experiment were the F_1 progeny of Charolais sires and Simmental dams. After weaning at approximately 8 months of age, they were purchased from a single commercial beef herd and loose-housed in two pens with straw bedding. The pens were equipped with electronically controlled feeding troughs (Insentec, Marknesse, the Netherlands) enabling accurate determination of individual feed intakes. An identical mixed diet consisting (as-fed basis) of maize (50.7%) and alfalfa silages (38.0%), alfalfa hay (3.0%), wheat meal (7.6%), and a mineral/vitamin mixture (0.7%) was given *ad libitum* to all the animals. The average chemical composition of the diet was as follows: dry matter (DM) 410 g/kg fresh weight, protein digested in the small intestine (PDI) 79 g/kg DM, net energy of fattening (NEF) 6.80 MJ/kg DM. Both bulls (B) and heifers (H) were assigned according to their live weight and age to two groups slaughtered at approximately 14 (group 14M – 6 bulls and 6 heifers) or 18 (group 18M – 6 bulls and 6 heifers) months of age.

Animal performance, slaughter and carcass characteristics

Individual feed intake was measured daily to determine DM intake (kg DM/day) and feed conversion ratio (DM intake/daily gain). The animals were weighed every 2 weeks at the same time of day throughout the experimental period, 3 days before slaughter (final weight, used for the calculation of daily live weight gain, feed intake and feed conversion ratio), and before transportation to the abattoir after approximately 18 h of fasting (slaughter weight, used for the calculation of killing-out and internal fat proportions).

When the target slaughter age was achieved, the animals were slaughtered in the experimental abattoir of the Institute of Animal Science (3 bulls and 3 heifers on each slaughter day). Within 1 h after slaughter, the carcasses were uniformly dressed and assessed by a trained classifier for conformation (an 18-point scale) and fatness (a 15-point scale) according to the EU beef carcass classification scheme with the use of subclasses [Commission Regulation (EC) No. 1249/2008]. The weights of hot carcasses and internal fat depots (kidney, rumen and cod/udder fat) were recorded. The killing-out percentage was calculated as (hot carcass weight/slaughter weight) × 100. After cooling for 24 h, the weights of both carcass sides were recorded and the right sides were divided into standardised joints. The joints were separated into lean meat, bones and tendons, and separable fat (subcutaneous and intermuscular), and their weights were recorded. The total meat yield was calculated as the lean meat from all joints plus the lean trimmings. High-priced meat was determined as the total weight of lean meat from the trimmed rump, shoulder, loin and tenderloin, and low-priced meat as the lean meat from the remaining joints plus the lean trimmings. The *musculus longissimus lumborum* (MLL) area and subcutaneous fat thickness were measured at the section between the 8^{th} and the 9^{th} ribs.

Muscle sampling and analyses

On the day after slaughter, muscle samples from MLL between the 9th and the 11th ribs were collected from right carcass sides and transported to the laboratory. The pH values were obtained 24 h after slaughter (pH_{24}) using an InoLab pH 730 set (WTW, Weilheim, Germany). Meat colour (L^*, lightness; a^*, redness; b^*, yellowness) was measured at three spots 24 h after slaughter using a portable spectrophotometer (CM-2500d, Minolta, Osaka, Japan). Drip loss during the storage period 24 h to

48 h after slaughter was determined as described by Honikel (1998).

After removal of the subcutaneous fat and epimysium, the samples intended for chemical analyses were homogenised in a food blender and frozen at −20°C until being analysed. Dry matter content was determined by the method of oven drying (105°C) to a constant weight. Dried samples were pulverised using a Grindomix GM 200 knife mill (Retsch, Haan, Germany) and analysed for crude protein (Kjeltec 2400, sampler unit 2460, FOSS Tecator AB, Höganäs, Sweden) and crude fat by extraction with petroleum ether (Soxtec Avanti 2055 manual extraction unit, FOSS Tecator AB, Höganäs, Sweden). The hydroxyproline content was determined by acid hydrolysis in accordance with Bergman and Loxley (1963). Total collagen was calculated as hydroxyproline × 7.25 and expressed as g of collagen per kg of fresh meat.

Two 2 cm thick steaks from each animal were vacuum packed, aged at 4 ± 1°C for either 4 or 11 days, and then frozen and stored at −18°C until further analysis. Before each sensory session, steaks were thawed at 4 ± 1°C for 24 h. The steaks were cooked in a double plate grill (VCR 6l TL, Fiamma, Aveiro, Portugal) preheated at 200°C until the internal temperature of 75°C was reached, as determined by a digital temperature probe (AD14TH, Ama-Digit, Kreuzwertheim, Germany). Then they were removed and immediately cut into approximately 2 × 2 × 2 cm cubes, taking care not to use their peripheral parts. The cubes were placed in covered glass containers and stored at 60°C until evaluation. Samples were presented to the sensory panel composed of ten trained and experienced panellists. The evaluations were performed in individual booths with red lighting to mask appearance differences. Two sets of 4 samples were presented to each panellist in each of the six sessions in total and the order of the test samples was randomised among the panellists. On a nine-point scale, the panellists evaluated the intensity of odour and flavour typical of beef (1 = very low, 9 = very high), tenderness (force required to compress the sample with the molars; 1 = very tough, 9 = very tender), juiciness (perception of moisture after 3–4 chews; 1 = very dry, 9 = very juicy), and overall acceptance (1 = non-acceptable, 9 = very acceptable).

For Warner Bratzler shear force measurements, the cooked samples, 1 cm^2 in cross section, were left at room temperature for approximately 2 h. The peak force needed to shear the sample across fibres was recorded using an Instron Universal Texture Analyzer 3365 (Instron, Canton, USA) equipped with a Warner Bratzler shear device.

Statistical analyses

Data were analysed using the MIXED procedure of SAS (2006). The statistical model for animal growth performance, carcass traits, chemical composition and physical properties of MLL samples involved the fixed effects of sex, age at slaughter and their interaction. The statistical model for sensory characteristics involved the fixed effects sex, age at slaughter, ageing time plus all interactions and the random effects of animal, assessor and session. The data in the tables are presented as least square means (LSM) and standard errors of the mean (SEM).

RESULTS

Growth performance, slaughter traits and carcass composition

Data for growth and slaughter characteristics are presented in Table 1. Bulls and heifers started the experiment and were slaughtered at a similar age. Bulls were, however, by almost 40 kg heavier ($P < 0.001$) at the beginning than heifers due to a higher weight gain during the pre-weaning period. As expected, bulls were heavier than heifers ($P < 0.001$) and the animals slaughtered at 14 months were lighter than those slaughtered at 18 months ($P < 0.001$) at the end of the fattening period. Compared to heifers, bulls gained more rapidly ($P < 0.001$) and consumed more dry matter daily ($P < 0.05$). The sex × slaughter age interaction was significant ($P < 0.01$) for feed conversion ratio (FCR = DM intake/daily live weight gain). While FCR was lower in heifers slaughtered at 14 months than in those slaughtered at 18 months ($P < 0.001$), there was no significant difference in FCR between age groups for bulls.

Hot carcass weights were higher in bulls compared to heifers ($P < 0.001$) and they were increased as the fattening period was extended both in bulls ($P < 0.001$) and heifers ($P < 0.05$). Bulls had higher killing-out proportion ($P < 0.05$), lower internal fat proportion ($P < 0.001$) and received lower fatness classification scores ($P < 0.05$) than heifers. Higher

Table 1. Growth performance and slaughter traits

	Bulls (B)		Heifers (H)		SEM	Significance[a] ($P < 0.05$)
	14M	18M	14M	18M		
	LSM	LSM	LSM	LSM		
Initial age (days)	254.3	252.5	251.7	246.5	4.7	
Slaughter age (days)	408.8	526.0	406.2	530.2	4.9	A
Initial weight (kg)	344.3	345.7	306.0	307.8	13.8	S
Final weight (kg)	554.3	698.0	478.7	553.7	16.5	S, A
Daily gain (kg/day)	1.35	1.31	1.14	0.93	0.06	S
DM intake (kg/day)	8.71	9.10	7.80	8.27	0.46	S
DM intake/daily gain	6.47	7.01	6.85	8.92	0.26	S, A, S × A
Slaughter weight (kg)	534.3	683.8	463.5	543.3	17.1	S, A
Hot carcass weight (kg)	302.3	388.2	256.1	299.6	8.9	S, A, S × A
Killing-out (g/kg)	565.7	568.7	552.5	551.5	6.5	S
Conformation[b]	8.2	9.0	8.0	8.0	0.3	
Fatness[c]	4.8	6.8	5.3	8.2	0.5	S, A
Internal fat (g/kg slaughter weight)	23.7	25.6	37.8	47.8	0.3	S, A

[a]S = significant effect of sex (bulls – heifers); A = significant effect of age at slaughter (14–18 months); S × A = significant effect of interaction

[b]Scale 1 = P^- (poorest) to 18 = S^+ (best)

[c]Scale 1 = 1^- (leanest) to 15 = 5^+ (fattest)

slaughter age significantly increased carcass fatness scores ($P < 0.001$) and internal fat proportion ($P < 0.05$).

Carcass composition traits are given in Table 2. Proportions of total and low-priced meat were higher and the high/low-priced meat ratio was lower in bulls than in heifers ($P < 0.05$). While bulls contributed to high-priced meat by a higher proportion of meat from the shoulder ($P < 0.01$), heifers had higher proportions of meat from the rump and loin ($P < 0.05$). The area of MLL was greater for bulls than for heifers ($P < 0.05$); when expressed per 100 kg of slaughter weight, however, no difference was found between the sex groups. Bulls produced leaner carcasses with a lower proportion of separable fat ($P < 0.001$) and lower subcutaneous fat thickness ($P < 0.001$) compared to heifers. The carcasses of 18M animals had lower proportions of high-priced meat, meat from rump, and bones and tendons than those of 14M animals, as well as lower high/low-priced meat ratio, higher proportion of separable fat and thicker subcutaneous fat layer ($P < 0.05$ and lower). Older animals also exhibited greater MLL area, although opposite results were obtained when the area was calculated per 100 kg of slaughter weight ($P < 0.05$).

Meat quality attributes

Higher pH values were measured in meat samples from older animals ($P < 0.01$), but the magnitude of the difference was rather negligible (Table 3). A sex × slaughter age interaction was manifested in the lightness (L^*) of meat. The MLL was lighter in bulls slaughtered at 18 compared to 14 months in contrast to the darker meat from older compared to younger heifers. Numerous significant effects were observed as to the chemical composition of MLL samples (Table 3). Bulls exhibited lower contents of dry matter ($P < 0.001$), protein ($P < 0.05$) and lipids extracted by petroleum ether ($P < 0.001$), and a higher level of collagen ($P < 0.001$) than did heifers. Slaughter age differences were demonstrated by higher contents of dry matter, lipids and collagen in older animals ($P < 0.001$).

Table 2. Carcass composition

	Bulls		Heifers		SEM	Significance[a] ($P < 0.05$)
	14M (LSM)	18M (LSM)	14M (LSM)	18M (LSM)		
Right side weight (g/kg)						
Total meat	778	776	761	751	4.9	S
High-priced meat	396	380	399	388	4.7	A
Meat from: shoulder	85	85	76	79	2.1	S
rump	249	233	259	241	2.4	S, A
loin	44	44	46	48	1.2	S
tenderloin	19	18	20	19	0.6	
Low-priced meat	382	396	361	363	3.9	S
Bones and tendons	192	182	189	184	3.2	A
Separable fat	30	42	51	65	4.2	S, A
Meat/bones and tendons	4.06	4.27	4.03	4.08	0.09	
High/low-priced meat	1.04	0.96	1.11	1.07	0.02	S, A
MLL area (cm^2)	60.1	71.6	57.8	58.6	2.7	S, A
MLL area (cm^2/100 kg slaughter weight)	11.3	10.5	12.5	10.8	0.5	A
Fat thickness (mm)	2.5	4.6	5.2	6.7	0.4	S, A

[a]S = significant effect of sex (bulls – heifers); A = significant effect of age at slaughter (14–18 months)

The results of the sensory analysis and Warner Bratzler shear force as affected by sex, slaughter age and ageing time of meat are summarised in Table 4. The sensory panel found no differences between the groups in beef odour intensity. Beef flavour intensity and juiciness were shown to be affected by slaughter age, as the older animals obtained higher values than the younger ones ($P < 0.01$ and $P < 0.05$,

Table 3. Physical properties and chemical composition of meat from MLL

	Bulls		Heifers		SEM	Significance[a] ($P < 0.05$)
	14M (LSM)	18M (LSM)	14M (LSM)	18M (LSM)		
pH_{24} value	5.44	5.49	5.43	5.46	0.01	A
Colour: lightness (L^*)	43.2	45.4	44.6	42.2	0.8	S × A
redness (a^*)	13.7	13.1	12.7	13.7	0.7	
yellowness (b^*)	13.9	13.9	13.8	13.0	0.5	
Drip loss 24–48 h (g/kg)	16.9	12.1	13.0	17.2	3.2	
Dry matter (g/kg)	237	246	252	266	2.7	S, A
Protein (g/kg)	203	204	207	212	2.2	S
Petroleum ether extract (g/kg)	11.9	20.2	21.6	36.2	2.4	S, A
Total collagen (g/kg)	3.9	5.5	3.3	4.2	0.2	S, A

[a]S = significant effect of sex (bulls – heifers); A = significant effect of age at slaughter (14–18 months); S × A = significant effect of interaction

Table 4. Sensory properties and Warner Bratzler shear force of grilled steaks from MLL

	Ageing time (days)	Bulls		Heifers		SEM	Significance[a] ($P < 0.05$)
		14M (LSM)	18M (LSM)	14M (LSM)	18M (LSM)		
Beef odour intensity	4	5.41	5.47	5.57	5.76	0.30	
	11	5.48	5.56	5.32	5.22		
Beef flavour intensity	4	5.20	5.87	5.59	5.60	0.29	A
	11	5.29	5.54	5.48	6.19		
Tenderness	4	4.98	6.07	5.32	6.37	0.39	S, A
	11	5.36	5.57	6.02	6.74		
Juiciness	4	5.42	5.81	5.30	5.88	0.41	A
	11	5.29	5.13	5.39	6.16		
Overall acceptance	4	5.30	6.03	5.50	6.07	0.39	S, A, S × Ag
	11	5.05	5.75	5.78	6.56		
WB shear force (N)	4	44.60	42.40	36.60	33.80	3.94	S
	11	42.30	35.50	34.50	31.70		

[a]S = significant effect of sex (bulls – heifers); A = significant effect of age at slaughter (14–18 months); Ag = significant effect of ageing (4–11 days); S × Ag = significant effect of interaction

respectively). Values of tenderness were lower in bulls compared to heifers ($P < 0.001$) and went up with the increasing slaughter age ($P < 0.001$). Older animals obtained higher scores for overall acceptance ($P < 0.001$). A sex × ageing time interaction for overall acceptance ($P < 0.05$) was due to lower values for 11 days-aged samples for bulls while the opposite trend was shown for heifers. The sensory panel assigned a higher score for overall acceptance ($P < 0.01$) to heifers compared to bulls only in the samples aged for 11 days.

DISCUSSION

The experiment was performed with the aim to evaluate the effect of sex and age at slaughter on animal growth and feed intake, carcass characteristics, and physical, chemical and sensory properties of MLL samples. The animals were purchased from a single farm where they had been reared under identical production conditions. Both bulls and heifers entered the experiment at a similar average age and were slaughtered after 155 (group 14M) or 274 (group 18M) days on feed. A higher growth ability for bulls compared to heifers, as shown in this study, has been well documented previously (Tanner et al., 1970; Steen, 1995; Link et al., 2007), although in most earlier studies the animals were not slaughtered at fixed slaughter ages as in the present experiment. The differences between the age groups in live weight gains were of smaller magnitude in bulls than in heifers, suggesting the capacity of bulls fed *ad libitum* to maintain fast growth until higher age or slaughter weight.

The effect of sex was a significant source of variation for the daily intake of DM in our study, possibly due to higher live weights and thus higher maintenance requirements of bulls compared to heifers. No difference in feed intakes between beef bulls and heifers of the same live weight was reported by Steinwidder et al. (2007). Similar feed intake capacity was also observed in bulls and heifers of Danish Black and White cattle (Ingvartsen et al., 1992). In our study, bulls had better (i.e. lower) FCR than heifers. Our results are broadly in agreement with the study of Ingvartsen et al. (1992), who reported by 22% lower FCR for bulls compared to heifers. Similarly, bulls were previously shown to produce carcass gain more efficiently than did heifers at either *ad libitum* or restricted feed intake (Steen and Kilpatrick, 1995). Feed conversion deteriorated as slaughter age increased, this being far more pronounced in heifers than in bulls. As in our study, animals consumed more DM of feed per 1 kg live weight gain with increasing days on feed in previous studies with Charolais and Limousin (Mandell et al., 1997b) and Hanwoo (Kwon et al., 2009) steers. Also, Jenkins and Ferrell (1984) had reported that bulls were more feed efficient than heifers at *ad libitum* feed intake and the efficiency was reduced with time on feed. In contrast to our results, however, those authors had observed similar decreases in efficiency for both bulls and heifers. The differences in FCR between sex and age groups might be attributed to several biological mechanisms, e.g. different body composition, protein turnover or tissue metabolisms of animals (Richardson and Herd, 2004).

The lower killing-out proportion for heifers was mostly due to their markedly higher deposition of internal fat compared to bulls. This is in agreement with other studies comparing carcass traits in bulls and heifers (Steen, 1995; Frickh et al., 2002; Velik et al., 2008). As expected, all fatness characteristics were significantly affected by both sex and slaughter age. Heifers were fatter than bulls at both slaughter ages and all animals produced more fat with increasing age, although this was more the case for heifers. Similar effects of sex and increasing slaughter weight on fat deposition were previously reported for different breed crosses (Steen and Kilpatrick, 1995).

Carcass dissection data analysis revealed a number of sex and slaughter age effects. Bulls had generally heavier, more muscular and leaner carcasses than heifers. Also, the distribution of meat in the carcass was different between the sexes. Although the proportion of meat from the most valuable carcass cuts was similar between the sexes, bulls contributed to this proportion more with the meat from the shoulder while heifers with the meat from the rump and loin. Bulls clearly showed a higher muscle development in the forequarter, while heifers had a higher proportion of meat in the hindquarter. Our results were generally in agreement with other studies comparing the carcass composition of bulls and heifers of different breeds (Steen and Kilpatrick, 1995; Link et al., 2007). Older animals produced carcasses with lower proportions of high-priced meat, especially the meat from the rump, lower high/low-priced meat ratio, smaller MLL area per 100 kg slaughter weight, and increased characteristics of fatness. A longer finishing period resulted in significantly lower proportions of lean meat in most hindquarter joints and in significantly higher proportions in two of the eight forequarter joints in serially slaughtered steers (Keane et al., 1989), which is in a good agreement with our results. In the study by Steen and Kilpatrick (1995), increasing slaughter weight was also associated with increased carcass fatness, reduced meat and bone proportions, and reduced meat proportion in high-priced joints of bulls and heifers.

Although significant, the differences between the age groups in carcass pH measured 24 h after slaughter were small. Because the values ranged from 5.35 to 5.60, this should not represent an increased risk of a negative impact on meat quality. Indeed, only pH_{24} values higher than 5.8 are considered as devaluating meat quality. Severely deteriorated quality parameters for beef, especially lower tenderness and increased water holding capacity, are associated with pH_{24} above 6.0 (Mach et al., 2008). These authors also noted that the incidence of meat pH_{24} ≥ 5.8 tended to be more frequent in males than in females and that females with lean carcasses tended to be more susceptible to having meat pH_{24} ≥ 5.8 than males. In agreement with our results, previous studies observed no pH_{24} differences between bulls and cows with the same type of pre-slaughter housing (Jeleníková et al., 2008), or between bulls and heifers of different breeds (Hoving-Bolink et al., 1999).

Meat colour plays an important role in a consumer's purchase decision and may be influenced by a number of pre- and post-slaughter factors (reviewed by Mancini and Hunt, 2005). Meat lightness is often inversely correlated to haem iron content, which increases with age (Chambaz et al., 2003). A part of the lightness variation can also be explained by changes in ultimate pH and intramuscular fat content (reviewed by Priolo et al., 2001). The increase of pH measured 48 h *post mortem* caused the deterioration of colour parameters in meat from different cattle categories (Węglarz, 2010). In the present study, however, lightness was affected by the interaction between sex and slaughter age of animals, and the meat became darker with increasing age only in heifers but not in bulls. We have no obvious explanation for this result.

Gender was previously identified as an important source of variation in beef intramuscular fat content, and an influence of sex hormones on the growth and development of intramuscular adipocytes was documented (Harper and Pethick, 2004). In our study, the content of intramuscular fat (petroleum ether extract) was almost twice as high in heifers than in bulls slaughtered at the same age. A similar extent of differences in dry matter and intramuscular fat contents were observed in MLL samples from purebred and crossbred Fleckvieh bulls and heifers (Velik et al., 2008). Intramuscular fat and dry matter contents increased with slaughter age, which is in agreement with the reports of Van Koevering et al. (1995) and Dubeski et al. (1997).

Higher total collagen contents were reported for bulls compared to steers (Cross et al., 1984b) and for bulls compared to cows of the same breeds (Jurie et al., 2005, 2006), apparently due to the effect of different testosterone levels. This supports our finding that the MLL samples of heifers contained less total collagen than those of bulls. In our study, older animals showed higher concentrations of total collagen, which is in contrast with the reported results of Jurie et al. (2005) that total collagen content in young bulls remained unchanged between the 15^{th} and the19^{th} months of age. Similarly, no effect of slaughter weight on total collagen contents in MLL from bulls of different breed types was observed by Sañudo et al. (2004) and Waritthitham et al. (2010).

Concerning the eating quality, meat from bulls is often considered inferior to that from heifers. However, there are few studies directly comparing the sensory properties of meat from cattle of both sexes reared and finished under controlled production conditions. Velik et al. (2008) reported higher scores for juiciness, flavour and tenderness in meat from heifers compared to bulls of different breed types and slaughtered at different endpoints. Juicier meat was also observed in Limousin heifers compared to Piemontese and Limousin bulls, which was attributed to their higher intramuscular fat content (Hoving-Bolink et al., 1999). Heifers in that study, however, had been slaughtered at a significantly higher age than bulls. In our study, meat from heifers was evaluated as more tender and, when aged for 11 days, more acceptable than meat from bulls. This finding was also supported by the Warner-Bratzler shear force measurements, the results of which were lower for heifers.

In the present study, most eating quality characteristics (flavour, tenderness, juiciness and overall acceptance) were positively influenced by age at slaughter. At least a part of the variation observed in the sensory properties can be attributed to differences in intramuscular fat, which considerably increased with slaughter age. Indeed, sensory characteristics are often related to intramuscular fat content, especially when its concentrations are highly variable among the samples compared (reviewed by Hocquette et al., 2010). Also, negative correlations were determined between intramuscular fat content and shear force of cooked meat in the recent study comparing the meat quality of bulls in fifteen European cattle breeds (Christensen et al., 2011).

Although total collagen content increased with slaughter age, meat from older animals was assessed by the sensory panel as more tender. Also, shear force values were numerically lower for these animals, though the differences were not statistically different. In agreement with our results, Jeremiah et al. (2003) concluded that insoluble collagen (not measured in our study) was more related to sensory tenderness traits than either total or soluble collagen. Similarly, collagen characteristics were shown to be a poor indicator of bulls' meat toughness and the role of differences in proteolytic enzyme activity and fibre type characteristics was suggested in the study by Christensen et al. (2011). Lower shear force measurements could also be associated with a lesser vulnerability of MLL to cold shortening in heavier and fatter animals (Sañudo et al., 2004).

Ageing time is one of the most important factors influencing most of the sensory properties, especially tenderness (Campo et al., 1999). In our study, sensory quality of meat aged for either 4 or 11 days was compared. A 7 days difference at this stage of the ageing process appears to be too short to influence significantly the scores for odour and flavour intensity, juiciness and overall acceptance, as the observed differences were rather small and inconsistent. Tenderness values were numerically higher as the ageing time increased in all groups except for, surprisingly, older bulls. At similar ageing times, our results were broadly in agreement with Monsón et al. (2005) who investigated the effect of ageing on meat from different cattle breeds. These authors stated that a major increase of tenderness was observed between the 1^{st} and the 14^{th} day of ageing.

CONCLUSION

In summary, the present study has shown clear differences between bulls and heifers slaughtered at two fixed ages in relation to performance, carcass traits and meat quality parameters. The bulls grew faster and more efficiently, had a higher killing-out proportion, and produced leaner carcasses with a higher proportion of total meat than heifers. The MLL of heifers compared to bulls contained more dry matter, protein and intramuscular fat, less total collagen, and it was assessed by the sensory panel as more tender and acceptable. The increase of slaughter age by 4 months resulted, especially in heifers, in reduced daily gain and feed conversion ratio as well as markedly higher fatness characteristics. Therefore, such an extension of the finishing period could not be considered advantageous for Charolais × Simmental heifers fed high energy diet.

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Corresponding Author

Ing. Daniel Bureš, Ph.D., Institute of Animal Science, Cattle Breeding Department, Přátelství 815, 104 00 Prague-Uhříněves, Czech Republic
Tel. +420 267 009 659, fax +420 267 710 779, e-mail: bures.daniel@vuzv.cz