Carcass characteristics and meat quality of bulls and steers slaughtered at two different ages

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ABSTRACT
This study was conducted to evaluate animal performance, carcase characteristics and meat quality of young bulls and steers (Charolais × Holstein-Friesian), fattened until 15 and 18 months of age. One half of 40 young bulls were castrated at 2 or 3 weeks of age. Starting at 7 months of age, they received grass silage supplemented with concentrates. At the end of the fattening period, the animals were slaughtered, and carcase quality and the quality of meat from Musculus longissimus thoracis (MLT) were evaluated. Bulls had a higher carcase dressing percentage, and their carcasses had higher lean meat content than steers. MLT from steers had higher intramuscular fat (IMF) content (by 0.89%); it was less tough, more tender and palatable. IMF from bulls had higher concentrations of polyunsaturated fatty acids (PUFAs) and a higher n-6/n-3 PUFA ratio than IMF extracted from steer meat. Older animals had higher carcase quality than those slaughtered at 15 months of age, and slaughtering at a later age had no negative influence on meat quality.

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Introduction
High-quality beef that meets consumer expectations can only be produced in beef and crossbred cattle herds characterised by high productivity (Sakowski et al. 2001). When dairy cattle production predominates, the quantity and quality of beef can be effectively increased through commercial crossing of beef bulls with dairy cows and creating herds for the purpose of beef production (Huuskonen et al. 2014). The offspring produced by commercial crossing are characterised by higher fattening performance and higher slaughter quality (Nogalski and Kijak 2001). Beef cattle breeds with a high growth potential such as Charolais are used for beef calf production based on dairy herds (Bureš and Barton 2012). Apart from cattle breed, the quality and sensory properties of beef are also affected by other factors, such as nutrition, slaughter age, body weight, sex category, pre-slaughter handling and meat aging (Modzelewkska-Kapitulak and Nogalski 2014; Nogalski et al. 2014; Purwin et al. 2016). In the group of beef cattle in Poland, young bulls and heifers are raised for meat rather than steers which remain underestimated. Castration reduces aggressiveness and sexual activity by decreasing blood testosterone levels, which is an important consideration in the pre-slaughter period because it prevents the depletion of energy reserves needed for lowering the pH of muscles (Steen 1995). Beef coming from steers currently has a high market share across the world (Reddy et al. 2015). In countries that are leaders in commercial beef production, meat from steers remains in high demand on specialty markets and it is sold to restaurants at high prices (Vieira et al. 2007). Some studies have investigated the effects of castration on slaughter value in cattle. Prado et al. (2015) demonstrated that beef from steers castrated at a later age and fed a diet with increased protein content was characterised by the highest sensory quality. The carcases of steers slaughtered at a later age, at higher body weights, had a lower percentage share of valuable cuts and higher fat content (Nogalski et al. 2014).
Steers fattened intensively until 18 months of age produced the most valuable carcasses (Nogalski et al. 2013). They were characterised by the highest weight of five most valuable cuts, and their meat had the highest intramuscular fat (IMF) content (4.71%), thus meeting the changing preferences of consumers. Reddy et al. (2015) found that fibrous feeds had a positive influence on meat colour but negatively affected marbling and tenderness. Beef tenderness is determined by the age at slaughter to a greater extent than by growth rates (Purchas et al. 2002). Charolais is a late-maturing breed and therefore Charolais cattle should be fattened intensively to heavy body weights (Bartoň et al. 2008). Crossing of Charolais with dairy Holstein-Friesians and, in particular, castration of the crossbred offspring are associated with a shorter fattening period and lower slaughter weight.

This study was conducted to compare the carcass characteristics and meat quality of young bulls and steers produced by crossing Charolais bulls with Polish Holstein-Friesian cows, and to determine their optimal slaughter age.

**Materials and methods**

**Animals**

The study was conducted in 2013–2014 upon the approval of the Local Ethics Committee for Animal Experimentation (decision no. 121/2010). The experimental materials comprised 40 crossbred calves produced by crossing Charolais bulls with Polish Black-and-White Holstein-Friesian cows. The semen of eight bulls was used for insemination. Calves of known origin purchased at 2 or 3 weeks of age were placed in a rearing facility at the Agricultural Experiment Station in Balcyń. The calves were kept in group pens (20 animals per pen) on deep litter. One half of the calves (1 pen) were castrated at purchase. Bloodless castration was carried out using a rubber elastat. The calves remained under veterinary care. Several cases of pneumonia and diarrhoea were recorded, and the animals received adequate treatment. The calves were fed milk replacer, hay and concentrate, followed by grass silage.

The animals were fattened from 6 months of age to 15 or 18 months. They were divided into groups based on sex category and the planned slaughter age, and were kept in group pens (10 animals per pen) on deep litter. Within sex categories, the calves were allocated to two pens by the analogue method, taking into account the sire. All animals had ad libitum access to grass silage; the concentrate was offered separately, upon request, in four portions per day (Table 1).

Experimental silage was made from a mixture of first-cut grasses (Lolium perenne, Phleum pratense, Festuca rubra, Poa pratensis) ensiled in horizontal silos without additives. Silage samples were collected before fattening and once a month during fattening, and were stored at −25 °C. Thawed samples were dried at 60 °C in Binder dryers and were ground in an ultra-centrifugal mill (ZM 200, Retsch, Haan, Germany) to a 1 mm particle size. Concentrate samples were collected together with silage samples. The proximate chemical composition, D-value and nutritional value of all feeds and the concentrations of carboxylic acids, fractions of structural carbohydrates [neutral detergent fibre (NDF), acid detergent fibre ADF and acid detergent lignin], water-soluble carbohydrates, pH, the content of buffer-soluble N, protein N, acid detergent-insoluble N and ammonium N in silages were

| Specification | Silage | Triticale | Rapeseed meal | Concentrate up to 300 kg | Concentrate above 300 kg |
|---------------|--------|-----------|----------------|--------------------------|--------------------------|
| Dry matter    | 397 ± 0.91 | 881 ± 0.96 | 887 ± 0.68 | 883.9 ± 1.12 | 885.5 ± 1.27 |
| On dry matter basis, g kg⁻¹ |        |           |                |                          |                          |
| Organic matter | 920 ± 2.46 | 981 ± 0.95 | 927 ± 1.05 | 932 ± 1.14 | 925 ± 1.39 |
| Crude protein | 141 ± 1.48 | 133 ± 1.32 | 388 ± 1.39 | 189 ± 1.15 | 163 ± 1.13 |
| NDF a | 569 ± 5.31 | 193 ± 1.63 | 310 ± 0.68 | 202 ± 1.21 | 184 ± 1.92 |
| ADF b | 387 ± 0.92 | 44 ± 0.65 | 228 ± 0.67 | 72 ± 1.85 | 31 ± 1.22 |
| DOMD c | 741 ± 1.91 | 932 ± 2.50 | 848 ± 1.42 | - | - |
| UFV d | 0.80 ± 0.03 | 1.21 ± 0.33 | 1.01 ± 0.05 | 1.18 ± 0.03 | 1.21 ± 0.02 |
| PDIN e | 82.2 ± 1.64 | 89 ± 0.38 | 259 ± 0.57 | 122.2 ± 0.41 | 112.4 ± 1.23 |
| PDE f | 69.3 ± 0.58 | 109 ± 1.03 | 163 ± 1.56 | 129.6 ± 1.26 | 121.3 ± 1.71 |

N = 9 for silage; N = 5 for triticale and rapeseed meal; N = 7 for concentrates.

Fermentation characteristics of silage: pH 4.8 ± 0.3; lactic acid: 21.4 ± 7.94 g kg⁻¹ DM; volatile fatty acids: 10.7 ± 1.98 g kg⁻¹ DM; water-soluble carbohydrates: 32.5 ± 19.1 g kg⁻¹ DM; NNH₃: 103 ± 67 g kg⁻¹ TN; true protein: 73.1 ± 6.48 g kg⁻¹ crude protein.

aNeutral detergent fibre.

bAcid detergent fibre.

cDigestible organic matter digestibility.

dMeat production units.

eProtein digested in the small intestine depending on rumen-degraded protein.

fProtein digested in the small intestine depending on rumen-fermented organic matter.
determined by the methods described by Purwin et al. (2010). Silage was administered twice daily in feed bunk (at 9 a.m. and 3 p.m.).

Bulls and steers were fed similar diets and received 35 g DM per kg W0.75 concentrate per day. The amount of concentrate offered to animals was adjusted at 14-d intervals, at control weighing before the morning feeding. The animals were fed two concentrate diets, to body weight of up to 300 kg and above 300 kg. The concentrate consisted of triticale grain, rapeseed meal and mineral–vitamin premix for beef cattle (Cargill, Warszawa, Poland), up to 300 kg BW: 72.5, 25 and 2.5% and above 300 kg BW: 78.5, 19, and 2.5%, respectively. Specific requirements were based on the INRA (2009) guidelines for medium-early maturing young bulls with daily gains of around 1000 g. The concentrate was provided in feeding stations (Insentec, Marknesse, the Netherlands) with an integral scale assembly for weighing the animals.

**Slaughter quality**

At the end of the fattening period, the animals were weighted (final body weight) and transported to a meat processing plant where they were kept in individual boxes with access to water for 15–20 h. The animals were stunned before slaughter. Carcase dressing percentage (percentage ratio of carcase weight to slaughter weight) was calculated. The carcasses were dressed and halved along the spine into two half-carcases that were chilled for 96 h at 4 °C. Electrical stimulation was not applied to the carcases. The value of pH48 was measured on carcase chilling, in the Musculus longissimus thoracis (MLT) between the 10th and 11th thoracic vertebrae. All slaughter and post-slaughter processes were carried out in accordance with the current meat industry regulations. Half-carcases were weighed within an accuracy of 0.5 kg, and conformation and fatness were evaluated based on the EUROP system criteria by a trained grader (Kien 2004).

Ninety-six hours postmortem, three-rib (10–12th rib) sections were sampled from right half-carcases (two cuts through a half-carcase, perpendicular to the spine, between the 9th and 10th, and the 12th and 13th thoracic vertebrae). Half-carcases were divided into primal cuts in accordance with the Polish Standard of 2003 (PN-88/A-82003/Apl.). Five most valuable cuts, passing through anatomical points of the half-carcase, i.e. shoulder (the upper portion of the front leg without the shoulder cartilage), fore ribs (separated by an anterior cut along the neck cutting line between the last cervical vertebra and the first thoracic vertebra; a posterior cut along the line between the 6th and 7th thoracic vertebrae; an inferior cut along the cutting line separating the thin flank, from the head of the first rib to the bottom edge of the iliocostalis), best ribs (separated by an anterior cut along the line between the 6th and 7th thoracic vertebrae; a posterior cut along the line between the last and last but one thoracic vertebrae; an inferior cut along the cutting line separating the thin flank, as above), loin (separated by an anterior cut along the line between the last and last but one thoracic vertebrae; a posterior cut along the line between the last lumbar vertebra and the first sacral vertebra; an inferior cut along a straight line, 5–7 cm from the muscles in the back) and round of beef (separated by an anterior cut along the line between the last lumbar vertebra and the first sacral vertebra, along the perimysium of the quadriceps femoris; an inferior cut along the cutting line separating the shank at the stifle joint), were weighed and their percentage shares in the right half-carcase were estimated.

Three-rib cuts were dissected, and the percentage content of soft tissues (lean meat, fat, tendons) and bones was determined. The surface area of MLT was outlined on wax paper, between the 10th and 11th thoracic vertebrae, and was measured with a planimeter.

**Chemical composition, physical and sensory properties of M. longissimus thoracis (MLT)**

During carcase dressing, MLT samples were collected from right half-carcases 96 h postmortem to evaluate beef quality. Meat samples weighing approximately 300 g were packaged in PA/PE vacuum bags at an ambient temperature of around 4 °C, under standard industrial conditions. In the laboratory, meat colour was evaluated based on the values of CIE-Lab coordinates, L* (lightness), a* (redness) and b* (yellowness) (CIE. 1978). Colour space parameters L*, a* and b* were measured three times by the reflectance method, using a HunterLab MiniScan XE Plus spectrophotometer, at different points over the muscle cross-section area. Colour measurements were performed on meat samples stored for 30 min at 4 °C, covered with foil permeable to O2 and impermeable to H2O. After colour measurements, each meat sample was divided into two portions: the first portion was used to determine the proximate chemical composition and physicochemical properties of meat, and the other portion was used to evaluate the sensory attributes of meat.

The analysis of the proximate chemical composition of meat included the determination of dry matter,
total protein, crude fat and ash, according to the procedure proposed by Wajda et al. (2014). The physico-chemical properties of meat included water-holding capacity and Warner–Bratzler shear force (WBSF). Water-holding capacity was determined based on natural drip loss and cooking loss. To estimate natural drip loss, approximately 20 g meat samples were packaged in polyethylene string bags and placed in an incubator at a temperature of 4 ± 1°C; after 24 h, the samples were dried and weighed again within an accuracy of 0.001 g; natural drip loss was calculated as the difference between sample weights before and after cold storage. Cooking loss was determined according to the method proposed by Honikel (1998): meat samples were weighed, they were packaged in plastic bags and placed in a water bath at a temperature of 80°C for 1 h, then the samples were cooled for 30 min under running water, dried and weighed again to determine their weight after cooking, and cooking loss was calculated as the difference between sample weights before and after heat treatment. WBSF values were measured using an Instron 5542 universal testing machine (Instron, Norwood, MA) equipped with a shear blade. Cylindrical core samples (1.27 cm in diameter, approximately 40 mm in length) were cut out with a cork borer in the direction of muscle fibres. The shear blade (V-shaped, with a triangular aperture of 60°) was applied perpendicularly to the fibre direction at a crosshead speed of 2 mm/s (Walsh et al. 2010). The test was performed at room temperature (~18°C). Data were processed using Bluehill 3 software (Instron, Norwood, MA).

The sensory attributes of meat were evaluated during four sessions because the animals were slaughtered in four batches. About 200 g meat samples were cut out across the muscle fibres and were cooked in a 0.6% NaCl solution (meat to solution weight ratio of 1:2) at a temperature of 96°C (±2°C). Pasteurisation was carried out until the temperature inside the sample reached 75°C. The sensory attributes of coded meat samples (aroma, taste, juiciness and tenderness) were evaluated on a 5-point scale (where 1 and 5 denoted the minimum and maximum score, respectively) by five trained panellists, selected based on their flavour sensitivity, according to Polish Standard (PN-ISO 4121:1998). The samples were presented to the panellists at room temperature (~20°C), in fluorescent light. The panellists assessed 10 meat samples during each session; each panellist received coded samples in the same order, and each sample was tested by all panellists. The samples were presented to the panellists at room temperature (~20°C), in fluorescent light.

**Fatty acid profile**

Fat was extracted from ground meat samples by the Soxhlet method using the Büchi B-811 extraction system, with hexane as a solvent. Crude fat content and the percentage share of fatty acids were determined based on the following standards: PN-EN ISO 5509:2001 and PN-EN ISO 5508:1996. Fatty acid methyl esters were obtained by dissolving the extracted fat in a methanol–choloroform–H₂SO₄ mixture, followed by methylation according to the modified Peisker method (Zegarska et al. 1991). The percentage share of 31 fatty acids was determined by gas chromatography, using the Varian CP 3800 system with a split/splitless injector and a flame-ionisation detector. Samples (1 μl) of fatty acid methyl esters were placed on a CP-Sil 88 capillary column (length: 100 m, inner diameter: 0.25 mm). Data were processed using the Galaxie Chromatography Data System. Fatty acids were identified by comparing their retention times with those of commercially available reference standards purchased from Supelco, Inc. (Bellefonte, PA). Analyses of samples and reference standards were performed under identical conditions, i.e. carrier gas – helium, injector temperature – 260°C, detector temperature – 260°C and initial oven temperature – 110°C, raised to 249°C. The fatty acids were divided into the following categories: saturated fatty acids (SFAs), unsaturated fatty acids (UFAs), including monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFAs). The following ratios were calculated: UFA/SFA, PUFA/SFA and n-6/n-3 PUFA.

**Statistical analysis**

Data were processed statistically using Statistica ver. 10.0 software (Statsoft 2015). The effects of cattle category and slaughter age on carcass traits and meat quality were determined by the least squares method, using the formula (1):

\[
Y_{ijk} = m + A_i + B_j + (AB)_{ij} + e_{ij}
\]

where \(Y_{ij} \) is the value of the analysed parameter; \(m \): population mean; \(A_i \): effect of cattle category (1, 2); \(B_j \): effect of slaughter age (1, 2); \((AB)_{ij} \): category × slaughter age interaction; \(e_{ij} \): random error.

**Results and discussion**

**Daily gain and carcass traits**

The animals slaughtered at 18 months of age had 15% higher final body weight compared to the animals slaughtered at 15 months of age (Table 2).
The difference in daily gains between bulls and steers was only 0.030 kg. According to Field (1971), bulls are predisposed to higher daily gains due to higher testosterone levels. The small differences in the final body weights of bulls and steers could result from group housing and energy losses in bulls due to mounting each other. Also, in a study by Schoonmaker et al. (2002), the daily gain of intensively fattened young crossbred (Angus × Simmental) bulls kept in group pens was only 0.020 kg higher than the daily gain of steers.

Sex category and the length of the fattening period had significant (p < .01) effects on carcase dressing percentage and fat content. Carcase dressing percentage was higher in heavier animals, which could result from higher carcase fatness, particularly in steers. In bulls castrated before reaching sexual maturity, androgen production is inhibited, and their carcasses contain more fat (Mach et al. 2008). An interaction between the factors was observed for fatness scores and dressing percentage. Older steers were characterised by higher carcase fatness and a lower dressing percentage than steers slaughtered at 15 months of age (Figures 1 and 2). Carcase conformation and fat cover scores affect the market price of beef cattle (Alberti et al. 2005). In a study by Barton et al. (2003), crossbred beef bulls slaughtered at 550 kg BW had a lower carcase dressing percentage than those analysed in our study (54.9%), at comparable average daily gains. The value of a carcase is significantly affected by the proportion of the most valuable cuts. Older animals produce carcasses with a lower proportion of high-priced meat, in particular meat from the round (Bures and Barton 2012). This relationship was also noted in the current study; the percentage content of primal cuts in the right half-carcase was lower for steers slaughtered at 18 months compared to 15 months of age (Figure 2).

**Table 2. Daily gain and carcase characteristics of fattened bulls and steers.**

| Traits                           | Category (C) | Slaughter age (SA) | p Value |
|----------------------------------|--------------|--------------------|---------|
|                                  | Bulls        | Steers             | 15 Months | 18 Months | SEM | C | SA | C × SA |
| Number                           | 20.0         | 20.0               | 20.0     | 20.0     | .356 | .623 | .756 |
| Initial body weight, kg          | 197.5        | 188.2              | 191.3    | 193.2    | 6.323 | .136 | .002 | .458 |
| Final body weight, kg<sup>a</sup> | 53.63        | 51.83              | 49.21    | 56.38    | 9.562 | .321 | .078 | .638 |
| Daily gain, kg/day               | 1.076        | 1.1                | 1.1      | 1.0      | 0.083 | .519  | .003 | .859 |
| Slaughter weight, kg<sup>b</sup> | 510.4        | 498.6              | 469.5    | 539.5    | 10.671 | .106  | .000 | .724 |
| Carcase weight, kg               | 300.3        | 284.1              | 268.0    | 316.7    | 6.464 | .004  | .001 | .903 |
| Dressing percentage, %           | 58.8         | 57.0               | 57.1     | 58.7     | 0.336 | .973  | .008 | .044 |
| Conformation score (pts)<sup>c</sup> | 7.6          | 6.6                | 6.2      | 8.0      | 0.302 | .721  | .001 | .903 |
| Fatness score (pts)<sup>d</sup>  | 4.8          | 6.1                | 4.4      | 6.5      | 0.376 | .973  | .008 | .044 |
| Weight of five primal cuts, kg<sup>e</sup> | 93.5        | 90.2               | 84.8     | 98.9     | 1.980 | .678  | .001 | .745 |
| Share of five primal cuts in the right half-carcase, % | 62.8 | 63.4 | 63.4 | 62.8 | 0.215 | .012 | .124 | .297 |
| MLT area, cm<sup>f</sup>         | 92.9         | 83.3               | 82.6     | 93.6     | 1.955 | .004  | .001 | .625 |

SEM: Standard error.

<sup>a</sup>Final body weight: body weight at the end of the fattening period.

<sup>b</sup>Slaughter weight: body weight before slaughter after transportation to the lairage and 15–20 h fasting with access to water.

<sup>c</sup>EUROP conformation: 1 muscling very weak (class P−) – 15 muscling outstanding (class E+).

<sup>d</sup>EUROP degree of fat cover: 1 none up to low fat cover (class 1−) – 15 very high (class 5+).

<sup>e</sup>Shoulder, fore ribs, best ribs, sirloin, round.

<sup>f</sup>MLT: M. longissimus thoracis.

**Figure 1.** Explanation of the interaction between category and slaughter age for carcase fatness. Significant differences between the means: **p < .01; error bars indicate the SEM.**

**Figure 2.** Explanation of the interaction between category and slaughter age for dressing percentage. Significant differences between the means: **p < .01; error bars indicate the SEM.**
cuts in the carcases of bulls and steers slaughtered at 15 months of age reached 63.4%, and it was 0.65% higher than in the animals slaughtered at 18 months of age. Girard et al. (2012) compared British crossbreds and Continental breed crosses and different slaughter ages and found that production systems focussing on increasing beef yield should incorporate Continental crossbreds, and that steers should be slaughtered at 18–20 months of age, i.e. later than in our study.

Musculus longissimus thoracis is a high-value section of the beef carcase, associated with lean meat content (Nogalski et al. 2014). In beef cattle, an increase in body weight is usually accompanied by an increase in the cross-sectional area of MLT (Keane 2003). In the present experiment, the cross-sectional area of MLT was larger in older animals, and the difference in this trait between bulls and steers reached 9.6 cm² on average, to the advantage of the former. This resulted from the lower body weight of steers and their lower carcase conformation scores. The quality of beef carcases is considerably affected by tissue composition (Table 3). Beef carcases with the highest lean meat content, the lowest bone content and the optimum fat content are in high demand (Kolczak 2008).

Significant (p ≤ .01) differences in the percentage content of lean meat and fat in three-rib cuts were found between bulls and steers. In comparison with steers, three-rib cuts from bull carcases had higher (by 8.04%) lean meat and lower (by 11.44%) fat content, and those findings are consistent with the results of carcase classification in the EUROP system (Table 2). Higher lean meat content and lower fat content in bull carcases are associated with the levels of testosterone which stimulates amino acid incorporation into proteins, thus increasing muscle weight without promoting fat deposition (Dayton and White 2008). In our study, age at slaughter had a significant influence only on bone content, which was lower in the carcases of animals slaughtered at a later age. Steen and Kilpatrick (1995) demonstrated that increasing slaughter age contributed to higher carcase fat content, particularly in heifers and steers, and to a lesser extent in bulls. The decrease in the bone content of three-rib cuts, noted in our study, resulted from increased fat deposition in older animals.

### The chemical composition, physical traits and sensory properties of meat

An analysis of the proximate composition of MLT revealed (p ≤ .05) the effects of sex category and slaughter age on carcase fat content (Table 4). IMF content was higher in bulls and steers slaughtered at a later age. Lengyel et al. (2003) reported an increase in IMF content in Holstein-Friesian steers with increasing slaughter age and body weight. Also according to Bruns et al. (2004) and Nogalski et al. (2014), fattening to higher weights significantly increases IMF content.

Beef quality is considerably affected by pH measured 48 h postmortem (Filipčík et al. 2009). Low meat acidification is one of the main reasons for bull castration. The lower pH of meat from steers, as compared with bulls, could result from lower testosterone levels in the former, which prevented the depletion of energy reserves needed for lowering the pH of muscles. In a previous study (Nogalski and Kijak 2001), high pH values typical of DFD (dark, firm and dry) meat were noted more frequently in the meat of dairy bulls and less frequently in dairy/beef crosses. In the present experiment, the analysed beef was characterised by normal pH 48h ranging from 5.52 to 5.57, regardless of cattle category and slaughter age (Table 4). Adequate pre-slaughter conditions, in particular the fact that the animals were kept in the lairage in individual boxes with free access to water, could have contributed to optimal pH levels.

Beef colour is considered as the most important quality attribute that determines consumer purchasing decisions (Kolczak 2008). The experimental factors analysed in our study had no significant effect on beef colour. Weglarz (2010) evaluated (48 h postmortem) the colour of the LT muscle in Polish Holstein-Friesian bulls and reported a similar value of parameter L (34.5) to that noted in our experiment. Apart from pH and colour, water-holding capacity is another determinant of the

### Table 3. Tissue composition of three-rib cuts.

| Traits                      | Category (C) | Slaughter age (SA) | p Value | SEM C  | SA  | C × SA |
|-----------------------------|--------------|--------------------|---------|--------|-----|--------|
| Weight of three-rib cuts, kg| Bulls 6.80   | Steers 7.34        | 15 Months 6.61 | 18 Months 7.52 | 0.247 | .268 .069 .571 |
| Share in three-rib cuts, %:  |              |                    |         |        |     |        |
| Fat                         | Bulls 15.81  | Steers 27.25       | 19.73   | 23.33  | 1.474 | .000 .097 .413 |
| Lean meat                   | Bulls 56.78  | Steers 48.74       | 53.20   | 52.32  | 1.025 | .000 .554 .162 |
| Bones                       | Bulls 22.23  | Steers 19.28       | 21.99   | 19.52  | 0.483 | .000 .002 .625 |
| Tendons                     | Bulls 5.19   | Steers 4.73        | 5.08    | 4.84   | 0.244 | .365 .631 .966 |
processing suitability of meat (Huf-Lonegran and Lonegran 2005). Meat from bulls and older animals was characterised by greater drip loss than meat from steers and younger animals, but the observed differences were not significant. WBSF, which characterises meat tenderness, depends on the structure of two main protein components of a muscle, i.e. proteins of intramuscular connective tissue and myofibrillar proteins. Their activity is determined by muscle type and animal’s age (Purslow 2005). An instrumental evaluation revealed that the meat of steers and younger animals was characterised by lower maximum cutting force than the meat of bulls and older animals, and the effect of sex category was significant ($p < .05$). Castration improves beef quality because it contributes to increasing IMF content (Heaton et al. 2006). IMF content is the key determinant of the sensory properties of meat (Hocquette et al. 2010). It characterises the amount of fat in skeletal muscles and appears in the form of fat isles (marbling) in selected beef cuts. In a study by Wheeler et al. (2005), the coefficients of correlation $r$ between IMF vs. WBSF, tenderness, juiciness and flavour scores were determined at 0.46, 0.47, 0.71 and 0.55, respectively. In our study, higher IMF content (Table 4) was associated with more desirable sensory attributes of (beef) (Table 5). In comparison with meat from bulls, meat from steers was characterised by higher values of tenderness and palatability.

**The fatty acid composition of meat**

Sex category affected the fatty acid profile of IMF (Table 5). The IMF of bulls had ($p < .01$) higher concentrations of PUFAs, including oleic acid, linoleic acid, conjugated linoleic acid, linolenic acid, arachidonic acid and eicosapentaenoic acid, than the IMF of steers. Fat extracted from the carcases of steers had higher MUFA levels, and the difference relative to bulls reached 4.61/100 g on average. The concentrations of n-6 and n-3 PUFAs were also significantly higher in the IMF of bulls, which resulted in a higher n-6/n-3 PUFA ratio (Table 5). One of the major risk factors for cardiovascular diseases in humans is too high dietary intake of n-6 PUFAs and too low intake of n-3 PUFAs, resulting in a high n-6/n-3 PUFA ratio (Breslow 2006). Age at slaughter had no effect on the n-6/n-3 PUFA ratio in the IMF of bulls and steers. The optimal n-6/n-3 dietary ratio of 5:1 was not exceeded (Breslow 2006), and it was more desirable in steers and animals slaughtered at a later age. Bilik et al. (2009) demonstrated that the fatty acid composition of meat from bulls was more favourable when they were fattened semi-intensively with a higher proportion of bulky feeds in the diet, compared with intensive fattening. The above findings were confirmed by Morales et al. (2012) who noted the lowest n-6/n-3 PUFA ratio in the IMF of MLD in grazed steers. De Smet et al. (2000) found that an increased fat content of bovine meat was paralleled by increased proportions of SFAs and MUFAs, and a decreased proportion of PUFAs. In the present study, a higher IMF content of meat was associated with a considerable increase in MUFA concentrations and a decrease in PUFA levels which could result from feeding grass silage *ad libitum*.

**Conclusions**

In the semi-intensive production system based mostly on grass silage, bulls did not achieve higher daily gains or final body weights than steers. The study revealed clear differences between bulls and steers slaughtered at two fixed ages in relation to

| Traits                  | Category (C) | Slaughter age (SA) | p Value |
|-------------------------|--------------|--------------------|---------|
| Dry matter, %           | Bulls        | Steers             | 15 Months | 18 Months | SEM | C SA | C × SA |
|                         | 25.51        | 26.36              | 25.60    | 26.27    | 0.249 | .061 | .133 | .083   |
| Fat, %                  | 1.78         | 2.67               | 1.81    | 2.64    | 0.278 | .045 | .046 | .091   |
| Ash, %                  | 1.09         | 1.07               | 1.08    | 1.07    | 0.004 | .087 | .124 | .216   |
| Protein, %              | 21.84        | 21.95              | 21.95   | 21.84   | 0.072 | .454 | .464 | .681   |
| pH<sub>48h</sub>        | 5.56         | 5.53               | 5.52    | 5.57    | 0.023 | .490 | .287 | .746   |
| L<sup>a</sup>           | 35.51        | 36.39              | 35.72   | 36.18   | 0.424 | .322 | .595 | .487   |
| a<sup>b</sup>           | 18.29        | 19.13              | 18.61   | 18.81   | 0.417 | .318 | .818 | .115   |
| b<sup>b</sup>           | 13.51        | 15.94              | 14.03   | 15.41   | 0.867 | .173 | .436 | .718   |
| Cooking loss, %         | 34.46        | 33.36              | 33.29   | 34.53   | 0.466 | .229 | .177 | .170   |
| Natural drip loss, %    | 2.48         | 1.99               | 2.20    | 2.27    | 0.221 | .247 | .854 | .079   |
| WBSF (N)                | 47.36        | 39.21              | 42.93   | 43.63   | 2.171 | .038 | .872 | .745   |
| Aroma                   | 4.45         | 4.82               | 4.59    | 4.69    | 0.064 | .216 | .287 | .487   |
| Tenderness              | 3.28         | 3.63               | 3.40    | 3.51    | 0.101 | .045 | .656 | .459   |
| Juiciness               | 4.01         | 4.10               | 4.06    | 4.03    | 0.061 | .465 | .807 | .807   |
| Flavour/Palatability    | 4.20         | 4.68               | 4.38    | 4.50    | 0.058 | .028 | .299 | .656   |

L: lightness; a: redness; b: yellowness; WBSF: Warner–Bratzler shear force.
performance, carcase traits and meat quality parameters. Bulls had a higher dressing percentage and produced leaner carcases with a higher proportion of total lean meat than steers. The MLT of steers, compared with bulls, contained more dry matter and IMF, it was less tough, and it was assessed by the sensory panel as more tender and palatable. The IMF of bulls, compared with steers, had higher concentrations of PUFAs and a higher n-6/n-3 PUFA ratio. Bulls and steers slaughtered at 18 months of age were characterised by higher carcase quality than those slaughtered at 15 months age, and slaughtering at a later age had no negative influence on meat quality.

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**Table 5. Content of selected functional fatty acids, fatty acid groups and ratios in M. longissimus thoracis.**

| Fatty acids in IMF, g/100g | Category (C) | Slaughter age (SA) | SEM | p Value | C | SA | C × SA |
|--------------------------|-------------|-------------------|-----|---------|---|----|-------|
|                          | Bulls       | Steers            | 15 Months | 18 Months |    |     |       |
| n-3                      | 1.969       | 1.244             | 1.413 | 1.811   | 0.119 | 0.000 | 0.21 |
| n-6                      | 5.218       | 2.707             | 3.592 | 4.389   | 0.343 | 0.000 | 0.094 |
| MUFA/SFA                 | 0.877       | 0.997             | 0.951 | 0.920   | 0.026 | 0.491 | 0.775 |
| PUFA/SFA                 | 0.154       | 0.087             | 0.109 | 0.134   | 0.009 | 0.000 | 0.176 |
| n-6/n-3                  | 5.218       | 2.707             | 3.592 | 4.389   | 0.433 | 0.094 | 0.209 |
| n-3                      | 1.969       | 1.244             | 1.413 | 1.811   | 0.119 | 0.000 | 0.021 |
| MUFA                     | 42.983      | 47.589            | 45.937| 44.532  | 0.789 | 0.002 | 0.272 |
| PUFA                     | 7.586       | 4.204             | 5.335 | 6.526   | 0.463 | 0.000 | 0.139 |
| PUFA/SFA                 | 0.154       | 0.087             | 0.109 | 0.134   | 0.009 | 0.000 | 0.176 |
| n-6                       | 5.218       | 2.707             | 3.592 | 4.389   | 0.433 | 0.094 | 0.209 |
| n-3                       | 1.969       | 1.244             | 1.413 | 1.811   | 0.119 | 0.000 | 0.021 |

TVA: trans-vaccenic acid; OA: oleic acid; LA: linoleic acid; CLA: conjugated linoleic acid; LNA: linolenic acid; AA: arachidonic acid; EPA: eicosapentaenoic acid; DPA: docosapentaenoic acid; SFA: saturated fatty acids; UFA: unsaturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

*Values of 2.96, 2.46, 2.06 and 2.36 for bulls 15, bulls 18, steers 15 and steers 18, respectively.

bValues of 1.15, 2.43, 1.30 and 1.19 for bulls 15, bulls 18, steers 15 and steers 18, respectively.
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