THE QUALITY OF STEER AND BULL MEAT OBTAINED BY CROSSING HOLSTEIN-FRIESIAN COWS WITH CHAROLAIS BULLS

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The aim of this study was to evaluate the quality characteristics of the muscles of bulls and steers obtained by crossing Holstein-Frisian cows with Charolais bulls. The material consisted of two muscles – musculus longissimus lumborum and musculus gluteus medius – obtained from the respective culinary elements of the loin and top sirloin. The muscles were examined for pH, drip loss, cooking loss, colour, chemical analysis, sensory evaluation and instrumental texture measurements. The meat derived from animals obtained by crossing was characterized by a satisfactory overall quality. It is also possible to increase the quality of this type of meat by performing castration surgery. As compared to the bull muscles, those obtained from steers were characterized by more favourable texture characteristics (fibrosity, hardness).

**Keywords:** Cattle breed, beef quality, collagen, castration, sensory characteristics, physicochemical properties

INTRODUCTION

The castration of male animals is a common practice in many countries specializing in the production of cooking beef in order to improve meat tenderness and palatability, which seem to be the most important characteristics of meat quality (Lehmann et al., 2017). In comparison to meat obtained from bulls, steer’s meat has a higher amount of fat with a white or whitish colour, as fat derived from well-fattened animals is yellow (Moran et al., 2017). The level of male hormones in the body of the animal plays a significant impact on the flavour of the meat. The meat obtained from older bulls has a distinctive flavour, which is a consequence of the presence of sex hormones. This flavour is undetectable in meat obtained from steers (Oliveira et al., 2017). The meat from this category of animals is a particularly valued commodity. Steer meat is tenderer than bull meat. This is due to the higher fat contents and the lower proportion of collagen in the meat (Lawrie, 2006). The most valuable meat is obtained from young steers and has a fresh, slightly aromatic smell, while the fat contents in meat from older steers is significantly higher (Lawrie, 2006; Nogalski et al., 2017). In the second half of the 20th century, the tradition of bull castration started to fade for many reasons, such as – low feed utilization by steers, the length of time required for fattening and the high fat contents in the meat (Biagini and Lazzaroni, 2007). However, a renewed interest in steer production has recently been observed due to the high quality of steer meat. At present, castration is conducted in order to obtain meat with specific properties. Additionally, castration reduces the aggressive behaviour of bulls, facilitates breeding and reduces the number of animal injuries (Marti et al., 2017). Raising steers requires higher expenditures than raising bulls, due to the longer period of fattening and worse feed conversion. However, the higher price of steer meat allows for the compensation of the higher costs of steer production (Biagini and Lazzaroni, 2007).

Among the various breeds of cattle raised for fattening, only meat cattle and its hybrids allow for obtaining satisfactory production results and culinary beef which meets the requirements of consumers. Increasing the quantity and improving the quality of the beef produced can be achieved by crossing commodity dairy cows with meat breed bulls and by creating herds of cattle to be used exclusively for their meat. The majority of the available data in the literature is concerned with meat from meat breed animals, while little data is related to meat obtained from animals derived by crossing commodity dairy cows with meat breed bulls. The meat obtained from these animals is a substantial part of the meat consumed in many countries. Therefore, the aim of this study was to evaluate the quality of the steer and bull meat obtained by crossing the commodity dairy cattle of the Holstein-Frisian breed with bulls of the Charolais meat breed.

MATERIALS AND METHODS

The material consisted of two muscles – musculus longissimus lumborum (M_LL) and musculus gluteus medius (M_GM). The research material was obtained from eight animals– steers and bulls derived by crossing the commodity dairy...
cattle of the Holstein-Frisian breed with bulls of the Charolais meat breed. The animals were obtained by the same group of breeders, were raised in the same farm and were fed according to the guidelines for semi-intensive fattening under strictly controlled conditions. The animals were fed ad libitum with grass silage with the addition of a concentrate mixture (post-extraction rapeseed meal, triticale middling and a mineral supplement). The used concentrate dosage was calculated based on the energy density dose recommended in the INRA nutrition and evaluation system (Dobrowolska, 1993), according to the models provided for animals of beef breeds or animals obtained by crossing. The animals were fattened to a mass of up to 550 kg and to an age of 18 months. They were then slaughtered in the same slaughterhouse at the same time. Seventy-two hours after the slaughter, when rigor mortis ended, the muscles comprising the appropriate research materials were removed from the carcases, vacuum packed and subjected to the ageing process at 2±1°C for 14 days. Measurements of pH, drip loss, colour and chemical analysis were conducted on the raw muscles. Sensory evaluation and instrumental texture measurements were performed on the muscles after they were heat treated by grilling and brief conditioning.

The grilling heat treatment was conducted using a two-sided cast-iron grill – with the top cover preheated to 190°C and the bottom cover preheated to 210°C. The steaks had a thickness of 2.5±0.2 cm and a weight of 250±30 g. The steaks were heat treated until the temperature in the geometric centre was 65±2°C (the steaks’ temperature was monitored using an electronic thermocouple). Then, the steaks were conditioned at 60°C for 6 minutes. This procedure helped to obtain the “medium” steaks (USDA, 2011).

The pH of the muscles was measured using a pH meter according to PN–ISO protocol 2917:2001. The colour measurement of individual muscles (eight replicates for each muscle) was performed using the CIE L*, a*, b* system, using a chroma meter CR-400 device from Konica Minolta. The following colour parameters were analysed: L* (lightness), for which the value ranged from 0 to 100; a* (colour axis ranged from greenness to redness), for which the value ranged from -60 to +60; and b* (colour axis ranged from blueness to yellowness), for which the value ranged from -60 to +60. During colour measurement, the shape of the samples was similar to cuboids of a size of about 8 cm x 4 cm x 2.5 cm. The measurements of the drip loss that occurred due to the ageing process and cooking loss were conducted using the gravimetric method by measuring the weights of the samples before and after ageing and after the heat-treatment process.

The protein content was determined using the Kjeldahl method. A conversion factor of 6.25 was used in the calculation of protein content (according to Polish PN–ISO protocol 75/A-04018/Az3). Fat was evaluated by diethyl ether extraction using the Soxhlet method according to PN–ISO protocol 1444:2000. The total moisture content was determined by drying the sample at 105°C (according to PN–ISO protocol 1442:2000). The hydroxyproline content in the meat was measured using the colorimetric method (according to PN–ISO protocol 3496:2000). On the basis of the hydroxyproline content, it is possible to calculate the collagen content using the 7.25 conversion factor (Korzeniowski et al., 2002). The fat from the meat was isolated using the Folch et al. (1957) method to determine fatty acid composition. The fatty acid profile was determined after converting the triacylglycerols present in the fat into fatty acid methyl esters by transesterification, followed by a qualitative and quantitative analysis of the esters by gas chromatography with a flame ionization detector (GC-FID). The preparation of fatty acid methyl esters was carried out in accordance with the test procedure described in ISO protocol 12966-2:2011.

The sensory evaluation was conducted using the Quantitative Descriptive Analysis (QDA) accredited method in accordance with the regulatory procedure described in ISO protocol 13299:2003. Twenty-five attributes were chosen and defined: colour (pink – grey), odour (roasted, burnt, sharp, meaty, liver-like, sour, fatty, other), taste (roasted, burnt, bitter, sour, meaty, liver-like, salty, sweet, other), texture (softness, ease of fragmentation, juiciness, ruddiness, fibrosity, fattiness) and overall quality. The intensity of the attributes was measured on a linear scale, and the results were converted into numerical values (from 0 to 10 arbitrary units [a.u.]). The evaluations were performed at the Laboratory of Sensory Analysis of the accredited Laboratory of Food Evaluation and Health Diagnostics, which meets all of the requirements specified in standard BS–EN–ISO 8589:2010. The sensory evaluations of the meat samples (in two replications) were conducted by an eight-person sensory panel of qualified assessors determined to be experts according to PN–EN ISO protocol 8586-03:2014. Individual samples of steaks weighing approximately 15 g were placed in previously prepared and coded (with three-digit random numbers) plastic containers (150 ml) and covered with lids. The individual samples were presented to the panellists at room temperature (21±2°C). Unsweetened tea (at a temperature of approximately 50°C) was used as the taste neutraliser between the evaluation sessions.

The instrumental measurement of the texture of the muscles was performed using the Warner-Bratzler attachment. The measurements were conducted on grilled steaks from which eight cylindrical samples with a diameter of 14 mm and a height of 15 mm were cut. The prepared samples were placed in an Instron universal testing machine (Model 5965, Instron, Canton, MA, USA) equipped with a Warner-Bratzler triangular-blade attachment. The crosshead speed of the blade was 250 mm/min (cell capacity of 500 N). Eight measurements of shear force were conducted for each sample. Statistical analysis of the results was performed using the Student's t-test at two levels of significance a=0.05 and a=0.1. The results were statistically processed using Statistica 10.0
Physical characteristics of muscles: Table 1 shows the pH, drip loss, cooking loss and colour values obtained for the M_GM and M_LL muscles derived from the steer and bull carcasses. The examined muscles belonging to the same carcass showed a different response to some of the tested quality factors. Castration was not found to have any clearly significant (p<0.05) influence on the meat pH, cooking loss or colour parameter a*. In each of the above mentioned parameters, values with statistically significant differences (p<0.05) were obtained for only one examined muscle – M_LL in the case of pH values and M_GM in the case of cooking loss values and colour parameter a*. These differences could be due to the different functions of and intensity of the work done by the tested muscles (Chikuni et al., 2010). In this experiment the M_GM and M_LL muscles which were derived from steers revealed higher (p<0.05) L* values, which proves that they were lighter as compared to the bull muscles. It was noted that values for the b* colour component were also significantly (p<0.05) dependent on the bull castration for two of the examined muscles. The values determined for the b* colour of the steer muscles were higher compared to the bull muscles. Trends similar to those found in the presented experiment are described in a number of publications, in which the research material was obtained from meat cattle animals (Dunne et al., 2004; McNamee et al., 2014; Moran et al., 2017). The castration of the animals had no effect on the amount of drip loss in this study, but this surgery had an impact on the content of the cooking loss, which was higher in the case of the bull meat, wherein a significant (p<0.05) difference was obtained only for one muscle – M_GM. The differences in the cooking loss content between the steers and the bulls was about 4% for the M_GM muscle and approximately 2% for the M_LL muscle (for which there was no significant [p>0.05] differences). Some authors have revealed differences in the content of cooking loss in meat derived from animals of the opposite sex, which is explained by the differences in the fattiness of the examined animals (Filipcik et al., 2009; Zhang et al., 2010). The revealed dependence of cooking loss content on bull castration can be an important factor in the sensory quality of meat as cooking loss content is negatively correlated with some of the features of the meat’s texture, for example, ease of fragmentation and juiciness, as was demonstrated by Adam and Abougroun (2015).

Chemical composition of muscles: The chemical composition of the examined muscles obtained from both steers and bulls was quite varied depending on the type of muscle tested (Table 2).

The results show that the dry matter content was higher (p<0.05) in the steer meat than in the bull meat. The same was found for the fat content in the M_LL muscle, while the reverse trend was observed in the case of the M_GM muscle for the collagen content. Bull castration did not exert a significant (p>0.05) effect on the amount of protein in both examined muscles. Data found in the literature on the impact of the sexual hormone levels on the chemical composition of meat indicate that steer meat has a higher fat content and a lower proportion of collagen without any differences in a protein content (Filipcik et al., 2009; Lazzaroni and Biagini, 2008; Zhang et al., 2010). The sex of the animal also determines fatty acid composition in intramuscular fat (Zhang et al., 2010). In this experiment, the level of sexual hormones affected (p<0.05) the amount of polyunsaturated fatty acids (PUFA) in both examined muscles, without significant (p>0.05) changes in the content of the saturated fatty acids (SFA). The steer muscles were characterized by a lower (p<0.05) PUFA content and the same amount of SFA. Additionally, it was noted that in the M_GM muscles obtained from steers the amount of monounsaturated fatty acids (MUFA) was significantly (p<0.05) higher relative to the content of these acids identified in the intramuscular fat of the bull muscles. The n6/n3 PUFA ratios determined in the presented experiment took the preferable values from the

Table 1. The pH, drip and cooking loss and colour parameters values in bovine muscles derived from steer and bull meat.

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Steers/Bulls</th>
<th>M_GM</th>
<th>M_LL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Steers</td>
<td>Bulls</td>
<td>Steers</td>
</tr>
<tr>
<td>pH</td>
<td>5.49±0.05</td>
<td>5.51±0.07</td>
<td>5.45±0.02*</td>
</tr>
<tr>
<td>Drip loss [%]</td>
<td>2.65±0.48</td>
<td>1.99±0.35</td>
<td>3.99±0.74</td>
</tr>
<tr>
<td>Cooking loss [%]</td>
<td>26.70±0.46*</td>
<td>30.66±2.65</td>
<td>28.83±2.76</td>
</tr>
<tr>
<td>Brightness L*</td>
<td>41.30±1.82*</td>
<td>40.76±1.07</td>
<td>42.07±2.03*</td>
</tr>
<tr>
<td>Redness a*</td>
<td>26.64±1.92*</td>
<td>23.57±1.33</td>
<td>21.65±1.81</td>
</tr>
<tr>
<td>Yellowness b*</td>
<td>13.45±1.31*</td>
<td>10.70±1.23</td>
<td>10.47±1.23*</td>
</tr>
</tbody>
</table>

* x ± SD; the results distinguished by the mark * differ significantly (p<0.05)
nutritional point of view regardless of the castration of bulls. The values of this ratio in the muscles obtained from steers were lower than those in the bull muscles (especially for the M_GM muscle), which could be due to a lower content of PUFA in steer muscles.

Sensory characteristics of muscles and instrumental measurement of muscle hardness: The results of the sensory evaluation showed a clear trend of higher ratings for the most evaluated traits of flavour and texture for steer meat than for bull meat, without regard to the overall quality of the meat (Fig. 1 A, B). For both examined muscles, a significant (p<0.1) variation was noted for sharp and liver-like odours. Additionally, the M_GM muscle had significantly (p<0.1) higher ratings for “other” odours (a buttery odour was most often noted by the members of the sensory panel), while there was a more noticeable sour odour in the M_LL muscles obtained from steers. The M_GM muscle derived from bulls was characterized by a significantly (p<0.1) higher intensity of roasted and meaty flavours than the steer meat, while sour and sweet flavours were more noticeable in the steer meat than the bull meat. A significantly (p<0.1) higher intensity of bitter, liver-like, sour and sweet flavours was noted in the M_LL muscles obtained from steers in comparison to those obtained from bulls. It is worth mentioning that meat obtained by crossing Holstein-Friesian cows with Charolais bulls achieved an assessment of the overall quality of about 6 a.u., which reflects good harmonisation of all of the evaluated attributes and indicates the ability of its wider use for culinary purposes using different types of cooking methods, including grilling. In general, the results of the sensory evaluation are in agreement with those of Gagaoua et al. (2016), who examined meat from 265 beef cattle of comparable chronological age and different genders.

The texture characteristics of the muscles examined using both the sensory and instrumental methods varied depending on the used muscles obtained from bulls and steers. In the case of textural properties defined using sensory evaluation, significant (p<0.1) differences were observed for softness and fibrosity.

Table 2. Content of protein, collagen, dry matter, fat and fatty acids in the M_GM and M_LL muscles obtained from steers and bulls.

<table>
<thead>
<tr>
<th>Muscles</th>
<th>M_GM</th>
<th>M_LL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers/Bulls</td>
<td>Protein [g/100g meat]</td>
<td>22.03±0.98</td>
</tr>
<tr>
<td></td>
<td>Collagen [g/100g meat]</td>
<td>0.70±0.06*</td>
</tr>
<tr>
<td></td>
<td>Fat [g/100g meat]</td>
<td>1.20±0.29</td>
</tr>
<tr>
<td></td>
<td>Dry matter [g/100g meat]</td>
<td>25.54±1.37*</td>
</tr>
<tr>
<td></td>
<td>SFA [g/100g fat]</td>
<td>45.98±2.81</td>
</tr>
<tr>
<td></td>
<td>MUFA [g/100g fat]</td>
<td>46.20±2.38*</td>
</tr>
<tr>
<td></td>
<td>PUFA [g/100g fat]</td>
<td>7.81±1.43*</td>
</tr>
<tr>
<td></td>
<td>n6/n3 ratio x ± SD</td>
<td>2.86±0.70*</td>
</tr>
</tbody>
</table>

x ± SD; the results distinguished by the mark * differ significantly (p<0.05)

Figure 1. The results of sensory evaluation were gathered using the QDA method for muscles obtained from steers and bulls: A) M_GM, B) M_LL. The results distinguished by the mark * differ significantly at the significance level of p<0.1. Symbol “o” means odour, “t” means taste.
The M_GM muscle derived from steers received higher ratings for softness than the muscles obtained from bulls, while ratings for fibrosity had the opposite trend. For the M_LL muscle, a significant (p<0.1) variation in texture characteristics was obtained for only one attribute, fibrosity; the muscles from steers received lower scores for fibrosity than the muscles from bulls. On the basis of the results of Warner-Bratzler shear force, it was noted that the castration of bulls exerted a significant (p<0.05) effect on the hardness of the meat. The M_LL and M_GM muscles obtained from steers were characterized by lower values of shear force than the bull’s muscles. The values of Warner-Bratzler shear force obtained for steers muscles were respectively 23.14±1.40 N for M_LL muscle and 24.60±5.10 N for M_GM muscle and in the case of bulls muscles 31.34±3.50 N for M_LL muscle and 32.20±4.30 N for M_GM muscle. The hardness of the steer muscles was approximately 23% lower than the bull muscles. The shear force results obtained for the different muscles translated into different values of muscle hardness (the M_GM and M_LL muscles isolated from the steers had a difference in muscle hardness of about 8 N compared to the muscles taken from the bulls). The obtained results may be due to the differences in the chemical composition of the meat (in this work the steer meat has a higher content of intramuscular fat [M_LL muscle] and a lower rate of connective tissue [M_GM muscle]). In the current literature on the impact of castration on the texture of meat authors have found lower values of shear force in steer meat than in bull meat, so results were similar to these received in this article (Filipcik et al., 2009; McNamee et al., 2014; Marti et al., 2011; Zhang et al., 2010).

Similarities and differences in the sensory characteristics, chemical composition and physical measurements of the tested muscles obtained from bulls and steers (PCA): The relationship between the obtained results of sensory characteristics, chemical composition and physical measurements of the tested muscles and the main components is shown in Figure 2. This projection shows the distribution of all obtained results on the plane formed by the selected two factors which were responsible for the variability of the samples in 98.26% (factor 1 and 2), in other words the projection is a correlation image of sensory, physical and chemical data. It was found that the tested muscles were characterized by a diversity of the evaluated parameters (in the projection, the meat samples were located far away from each other). The muscles obtained from steers stand out as having more intense red and yellow colours – they were characterized by a higher content of fat and MUFA than the other examined muscles. At the same time, the quality of these muscles depended more on the flavour trials than the bull muscles did (in the projection, the steer muscles were closer to the above mentioned sensory attributes than the bull muscles). The location of the bull muscles in a coordinate system built using two main components shows that they have a higher hardness (shear force), higher content of PUFA (muscle M_GM), higher content of cooking loss and n6/n3 ratio than the steer muscles. The closer together the plotted points (vectors) representing the input variables are, the stronger the positive correlation between the corresponding variables. Such relationships were observed between instrumentally assessed muscles hardness (shear force) and sensory evaluated fibrosity, for cooking losses and muscle colour and roasted taste, as well as for sensory evaluated muscles softness and their overall quality. Vectors representing muscle pH and sour odour lie on the same line but on opposite sides of the centre of the coordinate system variables which means that they are negatively correlated. The same is with cooking loss and sensory evaluated ease of fragmentation and ruddiness.

Conclusions: The results indicate that the meat derived from animals obtained by crossing was characterized by a satisfactory overall quality. It is also possible to increase the quality of this type of meat by performing castration surgery. The muscles obtained from the steers were characterized by more intense sharp and liver-like odours and also more intense sour and sweet tastes, higher dry matter, lower fibrosity, lower values of shear force, lighter colour with a more yellow hue and lower PUFA content relative to the bull muscles. Other quality characteristics did not differ
significantly depending on the castration surgery or obtained differences between the measured traits were significant only for one of the tested muscles.

REFERENCES


The quality of steer and bull meat


