Impact of the ageing process on the intensity of post mortem proteolysis and tenderness of beef from crossbreeds

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Abstract

The aim of the study was the evaluation of the effect of ageing on the extent of myofibril lar proteins degradation and tenderness of beef in different crossbreeds, BB × HF and SM × HF, from which the musculus semitendinosus was obtained. The pH value, basic composition of meat, and colour parameters were determined on the 3rd post mortem. The Warner Bratzler shear force and the extent of protein degradation were evaluated in regard to the effect of ageing time. Meat of BB × HF crossbreed had a lower amount of intramuscular fat and higher protein content (P ≤ 0.05). The shear force decreased with ageing time in the case of both crossbreeds. However, the highest values were noted in SM × HF crossbreed on days 3 and 7 of ageing. The differences in proteolysis of myofibrillar proteins and polypeptides, determined by SDS-PAGE electrophoresis, were observed between crossbreeds and the ageing time. A significant decrease in desmin and increased levels of 49-46 kDa and 32-27 kDa polypeptides (products of proteolytic degradation) were observed with an increasing ageing time. In addition, the rate of increase in the amount of 32-27 kDa polypeptides was more significant in BB × HF crossbreed. The data obtained showed that tenderness and the extent of protein degradation are associated with ageing process and animals’ genotype.

Keywords: beef, tenderness, proteolysis, electrophoresis.

Introduction

Meat tenderness is one of the most crucial determinants of meat quality as perceived by consumers (25), which along with other characteristics, such as tastiness, juiciness, freshness, and nutritional value, can provide valuable information for both producers and consumers during the whole production process (1, 12, 17, 24). Meat quality, particularly its tenderness, is determined by many variables: individual (breed, age, gender), environmental (diet, pre-slaughter stress), and post mortem (hanging and cooling method, ageing process, etc.). Tenderness is a result of many factors, such as amount and solubility of connective tissue, post mortem sarcomere shrinkage (rigor mortis), as well as the intensity of post mortem proteolysis of myofibrillar proteins (15).

One of the possibilities for improving meat quality is the application of ageing process, which is responsible for general post-slaughter changes in muscle tissue. This process is dependent on breed, age, gender, feeding and fattening systems, pre-slaughter stress, and metabolic status (6).

Many studies were conducted on the impact of breed and ageing on sensory and textural properties of bovine meat (19, 26). However, changes and differences in tenderness, determined by animal genotype, can be verified by biochemical analysis of changes in muscle proteins (e.g. using SDS-PAGE electrophoresis). Moreover, very few studies analysed the impact of breed on proteolysis intensity in muscle proteins during the ageing process.

Cross-breeding is a commonly used method in livestock production that enables the usage of indirect heredity of parental characteristics and heterosis (hybrids exuberance). This results in the enhancement of the quality and quantitative attributes in the offspring of crossbred animals. One way to quickly improve the
size of main carcass cut-outs is to use a breed with muscle hypertrophy, such as Belgian Blue or Piemontese, in a crossbreeding system (2).

Double muscling occurs in animals due to an increased number of muscle fibres (hyperplasia) and unlimited growth of muscle cells (hypertrophy) (20, 28). This effect is related to blocked expression of MSTN gene responsible for production of myostatin – a protein inhibiting muscle tissue development (21). Consequently, this leads to a better development of certain muscles (20). Double-muscled animals have significantly higher slaughter yield (higher proportion of muscle tissue to connective tissue and fat), better formation of the carcass, and a higher proportion of individual culinary fragments. Furthermore, it is believed that higher proportion of brighter muscles determines higher tenderness of meat obtained from animals with hypertrophy (2, 8).

The aim of this study was to determine the impact of ageing process on the extent of protein degradation and tenderness of the *musculus semitendinosus* obtained from Belgian Blue × Holstein-Friesian (BB × HF) and Simmental × Holstein-Friesian (SM × HF) crossbreeds.

**Material and Methods**

The study was conducted on 31 bulls between 17 and 19 months of age (BB × HF, n = 14, and S × HF, n = 17). The animals were bred in semi-intensive system on the same farm. They were transported to a local slaughterhouse located at a distance of less than 100 km. After 2 h of resting time in the lairage, the animals were slaughtered in accordance to internal regulations and under Polish General Veterinary Inspectorate inspection. The carcasses were chilled to 4°C within 24 h post mortem. Carcass weights were 324 ± 27 kg and 298 ± 18 kg for BB × HF and SM × HF crossbreeds, respectively. As regards carcasses classification, for BB × HF crossbreed, U conformation was class with 1+ and 2- fat cover degree, and for SM × HF, R conformation was class with 2- and 2+ fat cover degree respectively. The carcasses classification was performed according to the EUROV classification system (WE 1249/2008). After rigor mortis (48 h, 2 ± 1°C), the *musculus semitendinosus* was removed from each carcass. The muscles were then subjected to “wet” ageing process, through vacuum packing into barrier polyethylene bags and refrigerated storage (2 ± 1°C) for 3, 7, 14, and 21 d. After each ageing period, samples were frozen (-22 ± 1°C) using Küppersbusch “blast-freezer” and stored at -18°C until analyses. Thawing process was conducted at 2 ± 1°C for 24 h. After the defrosting process, the muscles were removed from their packages and 2.54 cm thick steaks were sliced.

**The pH measurement.** The pH measurement was performed according to the method described in ISO 2917: 2001/Ap1: 2002, using Testo 205 pH-meter with glass electrode, which was inserted directly into examined samples at 2 cm depth. Measurements were carried out in three repetitions with the mean value as the final result.

**Basic composition measurements.** Basic composition of bovine muscles (water, protein, fat, ash, and connective tissue content) was determined using Büchi near-infrared spectrometer NIRFlex N-500, according to Wyrwisz et al. (29). Measurements were conducted with the application of NIRFlex Solids module in the spectral range of 12 500-4000 cm⁻¹ in reflectance mode. Muscle portions (100 g) were homogenised and placed on a glass Petri dish, covering its whole bottom surface with a 0.5 cm thick layer. The measurement was performed in three repetitions using 32-fold sample scanning.

**Instrumental colour measurement in L*a*b* system.** Instrumental colour measurement in L* a* b* system of bovine meat was performed using Minolta CR-400 chromatometer (Konica Minolta, Inc., Tokyo, Japan), according to Wyrwisz et al. (30). L* - lightness ranged from 0 to 100%, a* - colour axis ranged from greenness (-a*) to redness (+a*), and b* - colour axis ranged from blueness (-b*) to yellowness (+b*). The diameter of the measuring head was 8 mm. The device was calibrated on a white standard plate (L* = 98.45, a* = -0.10, b* = -0.13). Illuminant D65 (colour temperature - 6500K) and standard observer (2°) were used. Ten measurements were conducted on the 3rd d of ageing for each sample (steak), in every quarter and in the central part of the steak.

**Shear force measurement.** Instrumental measurement of shear force WBSF was performed with a universal testing machine (Instron, 5965 model, MA, USA) with Warner-Bratzler add-on device, according to Wyrwisz et al. (29). Six cylindrical samples (1.27 cm x 2.5 cm) were cut using V-shaped blade. Shear force direction was perpendicular to the muscle fibers orientation. The test was carried out at constant speed of the measuring head (500 N capacity) – 200 mm/min, at standardised temperature of the samples (2 ± 1°C).

**Assessment of myofibrillar protein degradation using SDS-PAGE electrophoresis method**

**Sample preparation.** Myofibrils extracted from the samples in different ageing periods were prepared according to the procedure described by Fritz et al. (11) with the modifications of Koleczak et al. (14). Sample (2.5 g) without visible fat and connective tissue was homogenised with Ultra Turrax homogeniser (IKA T18 basic, Germany) with 5 mL of buffer (pH 6.8) containing 8 M urea, 2 M thiourea, 0.05 M Tris, 75 mM DTT, 3% SDS, and 0.05% bromophenol blue.

**SDS-PAGE analysis of myofibrillar proteins.** Myofibrillar proteins were resolved by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) in an “anykDa” gradient gel. The run was performed in a continuous buffer system using a Mini
Protein vertical slab gel unit (Bio-Rad Laboratories, Hercules, USA). The gels were stained with Coomassie blue G250. Destained gel images were acquired by the Gel Doc XR+ system (Bio-Rad Laboratories, Hercules, USA) using a white light conversion screen and analysed with the Image Lab software (Bio-Rad Laboratories, Hercules, USA) to determine the signal intensity (optical intensity) of the defined bands. Identification of the protein molecular weight was performed by comparison with a known molecular weight standard (precision plus protein standard-broad range, Bio-Rad Laboratories, Hercules, USA). Identification of bands was conducted by comparison with SDS-PAGE electrophoreograms obtained under comparable conditions by Marino et al. (17).

Statistical analysis. The results were analysed statistically with Statistica 10.0 programme (StatSoft Inc., Tulsa, USA). Significance of differences of the examined variables was verified using Fisher’s LSD test – the least significant difference at significance level of α = 0.05, α = 0.01, and α = 0.001 (ANOVA). The WBSF correlation of meat and products of proteolysis was determined using Pearson’s linear correlation, and the level of significance was set at P ≤ 0.05.

Results

Basic composition and colour of the semitendinosus muscle is presented in Table 1. The measurements of the basic composition and muscle colour were performed on the 3rd day post mortem. Significant differences in basic composition were observed in meat obtained from both crossbreeds. The muscles of crossbreed BB × HF animals were characterised by higher protein and lower intramuscular fat content than those of SM × HF crossbreed. There were no significant differences in water and connective tissue content between the examined crossbreeds. Slight differences between the crossbreeds were observed in meat colour parameters, although the differences were not significant.

Table 1. Mean ± SD of pH, basic composition and colour of semitendinosus muscle from crossbreeds BB × HF and SM × HF

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BB × HF (n = 14)</th>
<th>SM × HF (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.58 ± 0.081</td>
<td>5.54 ± 0.055</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>73.8 ± 0.981</td>
<td>72.8 ± 0.732</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>23.25 ± 0.462</td>
<td>21.92 ± 0.641</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>1.18 ± 0.153</td>
<td>1.55 ± 0.231</td>
</tr>
<tr>
<td>Connective tissue (%)</td>
<td>1.19 ± 0.113</td>
<td>1.37 ± 0.182</td>
</tr>
<tr>
<td>Colour coordinates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>41.1 ± 3.72</td>
<td>42.1 ± 3.94</td>
</tr>
<tr>
<td>a*</td>
<td>21.9 ± 4.72</td>
<td>22.8 ± 3.81</td>
</tr>
<tr>
<td>b*</td>
<td>12.5 ± 3.22</td>
<td>11.5 ± 3.51</td>
</tr>
</tbody>
</table>

(a, b, c) – means with different letters differ significantly (P ≤ 0.05)

The effects of ageing on shear force values in Warner-Bratzler test (WBSF) of the *musculus semitendinosus* are presented in Fig. 1. As expected, WBSF values decreased significantly in both crossbreeds from 3 to 21 d of ageing, reaching the lowest values on day 21 (39.3 and 48.1, respectively). However, in SM × HF crossbreed, the WBSF was the highest on the 3rd and 7th day of ageing. A significant decrease in WBSF value was noted in SM × HF after 14 d of ageing, while a significant improvement in tenderness was observed in BB × HF crossbreed after ageing for 7 d.

The effect of crossbreeding and ageing time on changes of the major myofibrillar proteins and products of proteolytic degradation in the *semitendinosus* muscle is shown in Table 2. The differences of changes in myofibrillar proteins affected by post mortem proteolysis were not significant in terms of the optical density of bands corresponding with MHC and actin proteins, which are involved in muscle contraction in both crossbreeds. MHC and actin were the most abundant proteins in the myofibril (34.77% - 37.17% for myosin, 19.38% - 20.55% for actin), regardless of the crossbreed and the day of ageing. However, there was a significant difference in the value of optical density intensity of the myosin band between the studied crossbreeds. A significantly higher (P ≤ 0.01) abundance of this protein was observed in BB × HF meat than in SM × HF meat. The effect of crossbreed was also demonstrated for tropomyosin (P ≤ 0.001) and troponin I (P ≤ 0.05), and polypeptides: 170 - 138 kDa (P ≤ 0.001), 92 - 68 kDa (P ≤ 0.01), 49 - 46 kDa (P ≤ 0.001), and 32 - 27 kDa (P ≤ 0.001). In addition, the 49-46 kDa and 32-27 kDa polypeptides were significantly affected by the ageing process (P ≤ 0.001). The amount of these polypeptides increased with ageing time. A significant decrease (P ≤ 0.01) in desmin by ageing was observed in both crossbreeds. Furthermore, there was no effect of ageing or crossbreeds on the amount of α-actinin and MLC1. Only in the case of Tn-T, 49-46 kDa (P ≤ 0.01), and 32-27 kDa polypeptides, was a significant difference (P ≤ 0.001) between crossbreed and ageing (C × A) observed.

The analysis of the results showed that the level of several myofibrillar proteins correlated with the value of shear force. The correlations between WBSF and desmin (r = 0.79; r = 0.78, P ≤ 0.05), and between WBSF and Tn-T (r = 0.87 and 0.76 P ≤ 0.05), were found for both BB × HF and SM × HF respectively.
**Fig. 1.** Warner-Braterzl shear force values (WBFS) of the semitendinosus muscle from crossbreeds SM × HF and BB × HF. (a, b...)- means with different letters differ significantly for SM×HF (P ≤ 0.05); (A, B...)- means with different letters differ significantly for BBxHF (P ≤ 0.05); (A, Y...)- means with different letters differ significantly for ageing day (P ≤ 0.05)

**Table 2.** Changes (%) in myofibrillar proteins and products of proteolysis affected by ageing (A) and crossbreed (C) in the *m. semitendinosus*

<table>
<thead>
<tr>
<th>Protein</th>
<th>(C)</th>
<th>(A)</th>
<th>MSE</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHC</td>
<td>BB × HF</td>
<td>36.65 ± 0.589</td>
<td>37.17 ± 1.404</td>
<td>36.43 ± 0.641</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>35.23 ± 1.027</td>
<td>34.77 ± 0.586</td>
<td>35.86 ± 0.908</td>
</tr>
<tr>
<td>170-138 kDa</td>
<td>BB × HF</td>
<td>2.11 ± 0.436</td>
<td>2.29± 0.144</td>
<td>2.33 ± 0.459</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>1.36 ± 0.371</td>
<td>1.58± 0.284</td>
<td>1.69 ± 0.448</td>
</tr>
<tr>
<td>α-Actinin</td>
<td>BB × HF</td>
<td>2.38 ± 0.280</td>
<td>2.41± 0.422</td>
<td>2.65 ± 0.273</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>2.21 ± 0.298</td>
<td>2.26± 0.318</td>
<td>2.36 ± 0.526</td>
</tr>
<tr>
<td>92-68 kDa</td>
<td>BB × HF</td>
<td>2.15 ± 0.165</td>
<td>2.32± 0.111</td>
<td>2.37 ± 0.274</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>1.95 ± 0.110</td>
<td>2.03± 0.064</td>
<td>2.09 ± 0.131</td>
</tr>
<tr>
<td>Desmin</td>
<td>BB × HF</td>
<td>2.06± 0.163</td>
<td>1.87± 0.135</td>
<td>1.81± 0.047</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>1.84± 0.094</td>
<td>1.80± 0.055</td>
<td>1.72± 0.109</td>
</tr>
<tr>
<td>49-46 kDa</td>
<td>BB × HF</td>
<td>0.57 ± 0.077</td>
<td>0.68± 0.073</td>
<td>0.74 ± 0.074</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>0.42± 0.068</td>
<td>0.48± 0.062</td>
<td>0.60± 0.135</td>
</tr>
<tr>
<td>Act</td>
<td>BB × HF</td>
<td>20.55± 0.491</td>
<td>19.47± 0.351</td>
<td>19.66 ± 0.822</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>19.85± 0.536</td>
<td>20.02± 0.190</td>
<td>20.18 ± 0.555</td>
</tr>
<tr>
<td>Tn-T</td>
<td>BB × HF</td>
<td>5.80± 0.297</td>
<td>5.21± 0.234</td>
<td>5.11± 0.127</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>5.41± 0.402</td>
<td>5.17± 0.318</td>
<td>5.06± 0.250</td>
</tr>
<tr>
<td>TPM</td>
<td>BB × HF</td>
<td>8.11 ± 0.397</td>
<td>8.08± 0.218</td>
<td>8.00 ± 0.151</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>7.52 ± 0.421</td>
<td>7.47± 0.298</td>
<td>7.38 ± 0.395</td>
</tr>
<tr>
<td>32-27 kDa</td>
<td>BB × HF</td>
<td>0.89± 0.116</td>
<td>1.94± 0.155</td>
<td>2.27± 0.165</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>0.72± 0.056</td>
<td>0.90± 0.118</td>
<td>1.12± 0.102</td>
</tr>
<tr>
<td>MLC1</td>
<td>BB × HF</td>
<td>3.27± 0.078</td>
<td>3.21± 0.146</td>
<td>3.16 ± 0.122</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>3.19± 0.246</td>
<td>3.12± 0.056</td>
<td>3.09 ± 0.085</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TnI</td>
<td>BB × HF</td>
<td>1.57± 0.128</td>
<td>1.52± 0.083</td>
<td>1.48 ± 0.088</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>1.48± 0.090</td>
<td>1.41± 0.144</td>
<td>1.35 ± 0.142</td>
</tr>
<tr>
<td>TnC</td>
<td>BB × HF</td>
<td>1.70± 0.139</td>
<td>1.63± 0.209</td>
<td>1.56 ± 0.130</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>1.53± 0.056</td>
<td>1.48± 0.114</td>
<td>1.42 ± 0.132</td>
</tr>
<tr>
<td>MLC2</td>
<td>BB × HF</td>
<td>2.74± 0.116</td>
<td>2.78± 0.167</td>
<td>2.83 ± 0.282</td>
</tr>
<tr>
<td></td>
<td>SM × HF</td>
<td>2.70± 0.142</td>
<td>2.73± 0.183</td>
<td>2.78 ± 0.159</td>
</tr>
</tbody>
</table>

* (X, Y)- means with different letters in a column show a significant effect of crossbreed (P ≤ 0.05); (a, b...)- means with different letters in lines show significant effect of ageing (P ≤ 0.05); * = P ≤ 0.05; ** = P ≤ 0.01; *** = P ≤ 0.001; NS - non-significant effect; D3, D7, D14 and D21 – *m. semitendinosus* aged 3, 7, 14, or 21 d respectively.
Discussion

Basic composition of the *m. semitendinosus* did not differ significantly between the BB × HF and SM × HF crossbreeds. However, protein and fat contents were significantly different. The intramuscular fat (IMF) content in the meat from BB × HF crossbreed reported in this work (1.18%) was lower than that from SM × HF crossbreed, but was slightly higher than the values found for meat (*m. longissimus thoracis*) obtained from Belgian Blue cattle (7, 21). These differences may be due to the fact that in the present study crossbreeds were used, while Cuvelier et al. (7) and Olivan et al. (21) used Belgian Blue pure-breed bulls. According to Christensen et al. (5), the Piemontese, Asturiana de los Valles, or Belgian Blue breeds, due to their hypertrophy, could be characterised as beef breeds with high muscularity and low level of fat. The content of intramuscular fat is affected by many factors (number and diameter of intramuscular adipocytes, ratio between uptake, synthesis, and degradation of triacylglycerols), but is negatively correlated with the protein content in beef meat (23). De Smet (8) suggested that in double-muscled animals, the IMF content is lower due to a decreased size of fat cells, not their decreasing number. There were insignificant differences in the amount of connective tissue between the studied crossbreeds, but the BB × HF was characterised by its slightly lower content. Previous studies (5, 19, 21) also reported low amount of total collagen content in double-muscled breeds, like Belgian Blue or Piemontese. It should be emphasised that the amount of connective tissue in *m. semitendinosus* obtained in this study from BB × HF crossbreed was lower in comparison with the data regarding the double-muscled animals (5, 21). The collagen content is an important factor determining bovine meat tenderness, which is different for each cattle breed. Higher collagen content is found in British breeds, such as Angus, while the lowest is observed in continental breeds such as Limousin or in double-muscled animals. This was confirmed by Chambaz et al. (4), who observed higher content of collagen in meat obtained from Angus cattle in comparison to Limousin. On the other hand, meat from Belgian Blue animals had lower content of collagen when compared with Limousin (18, 22).

No significant differences were observed in each colour coordinates between BB × HF and SM × HF crossbreeds. These results were in opposition to most of the data reported in the literature, showing that meat from double-muscled animals is lighter and has less pigmentation than that of normal-muscled animals (7, 21, 22). Some authors suggested that paler colour of meat from double-muscled animals is related to the higher proportion of white fibers in muscle tissue (8, 9, 21). This may be related to a different system of feeding or animal genotype (crossbred vs. pure-bred animals).

The ageing process leads to improvement of meat tenderness (decrease in WBFS values), regardless of crossbreed genotype. WBFS values determined in this study were similar to the results obtained by other authors (3, 27). However, in some other publications, higher values of WBFS after 8 d of ageing for the *longissimus thoracis* muscle from double-muscled animals have been demonstrated in comparison to meat from normal animals (10). Christensen et al. (5) also showed higher values (67.4N) of WBFS after ageing for 10 d in the *m. longissimus thoracis* of Simmental bulls. It is suggested that the differences in tenderness of beef meat are mainly determined by the specific animal breed, e.g. meat obtained from double-muscled animals has better tenderness. This effect can be explained by a lower collagen content and its more favourable cross-linking, as well as longer muscle fibers compared to normal animals (3, 5, 21).

The influence of ageing on myosin (MHC) and actin (ACT) degradation was insignificant in the present study. However, the levels of these proteins varied between the crossbreeds. In the case of actin and myosin (both heavy and light chains), numerous publications have indicated no changes (13, 14) or only slight changes in MHC levels as a result of the post mortem proteolysis (17). Marino et al. (17) observed the effect of ageing time on the abundance of MHC only for Podolian breed. In addition, the level of this protein was significantly lower compared to the Friesian breed and Romagnola × Podolian crossbreeds during all ageing times. In the case of actin, these authors observed no impact on ageing process and the genotype of animals or interaction of both (17). As a result of the ageing process of beef, some proteins are degraded, leading to a decrease in their amount and an increase in the content of degradation products. In this study we observed a decrease in troponin-T, desmin, MLC1, and troponin C, simultaneously with an increase in polypeptides from 49-46 kDa and 32-27 kDa which formed as a result of the ageing process. In addition, the content of polypeptides 49-46 kDa and 32-27 kDa differed significantly between crossbreeds. These data are similar to the results obtained by Marino et al. (17) and Kołczak et al. (14). Marino et al. (17) also observed a greater degradation of troponin T between 1 and 21 d of ageing compared to the Friesian breed and Romagnola × Podolian crossbreeds (30% vs. 16% respectively). Mahet et al. (16) and Koohmaraie and Geesink (15) suggested that the changes in myofibril architecture that occur during ageing have a direct effect on post mortem beef tenderisation. Degradation of proteins responsible for maintaining the myofibril structure leads to its weakness and is associated with improvement in meat tenderness (13, 14, 17). Therefore, the changes in proteins forming myofilaments and sarcomere structure, including troponin T, desmin, α-actinin, and the content of the products of their degradation, i.e. 49-46 kDa and 32-27 kDa polypeptides may be the key to improvement of
beef tenderness. Furthermore, significantly higher amounts of selected myofibrillar proteins and polypeptides (MHC, TMP, TnI, and all groups of polypeptides) in BB × HF crossbred were demonstrated in the present study. This relationship is probably related to a higher content of proteins in double-muscled animals.

Therefore, the value of the WBSF decreases with the extended period of ageing. It could be explained by a significant correlation between the textural properties of meat and proteolytic degradation of myofibrillar proteins, the content of which is animal genotype-dependent. Our study demonstrated that improvement of meat tenderness is associated with troponin-T and desmin degradation and increased amount of polypeptides, e.g. those with molecular weight of 27-32 kDa, during the ageing process. Understanding the mechanism of proteolytic processes occurring in the meat immediately after slaughter and during ageing may lead to improvement of the quality of beef.

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