The effect of genotype on sensory and technological quality of beef

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ABSTRACT
Quality of meat represents one of the most important current issues in modern cattle production. It is known that breed and genetics are the most important pre-slaughter factors which influence the quality of meat. In Serbia, most of the meat that can be found on the market derives from domestic cattle of Simmental breed (80%) whose carcass and meat quality do not satisfy the demand of consumers and meat industry. Industrial crossing of Domestic Simmental breed with French fattening breed is fast and efficient method for improvement of mentioned properties. In this paper, results of the research of sensory and technological quality of meat from Domestic Simmental cattle and its F1 crosses with Charolais and Limousin breed (N=96) are presented. Genotype significantly (p<=0.01) influenced sensory meat properties. The best color (3.59/5) and consistency (2.84/3) was established in crosses with Limousin, whereas the most distinct marbling was determined in Domestic Simmental breed (2.80/5). Genotype had no significant effect on investigated properties of technological meat quality, except pigment content (p<=0.01). The highest value of this trait was established in domestic breed (101.9 p.p.m.), which was in accordance with visually evaluated lighter nuances of meat color in crosses. Crosses with Limousin breed realized slightly better water holding ability (9.08 ml) and lower cooking losses (38.02) compared to other genotypes, whereas pH24 value was statistically different (p<=0.05) between domestic breed (5.61) and Charolais crosses (5.56). The greatest diameter of muscle tissue (62.94 µm) and the greatest shear force (8.49 kg) were determined in domestic breed. The highest protein content was established in meat from Limousin crosses (22.79%). Content of fat in meat, contrary to low evaluated marbling, was the highest in the meat of Charolais crosses (1.59%).

Keywords: genotype, crossing, beef, quality properties

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INTRODUCTION

Definition of meat quality is very complex and it can be considered from different aspects: technological, nutritional, health aspect, etc. However significant role have consumer demands especially in regard to fat content, color, marbling and tenderness of meat. Researches of the inclinations of consumers in Serbia (Ostojić et al., 2005) showed that meat color has decisive role in choice of beef, followed by marbling and tenderness of meat. Average consumer in Serbia prefers meat of lighter nuances of red and medium degree of marbling. On the other hand, meat processing industry is more interested in technological quality of meat, i.e. in properties which are important for processing and final appearance and quality of finished products.

Quality of meat, as a result of many factors (pre-slaughter and post-slaughter), is susceptible to variations. Breed, that is genetic factors represent pre-slaughter factors of great importance to the quality of meat. According to recommendations by certain authors (Miščević et al., 2003; Bogdanović et al., 2005), fast and efficient improvement of mentioned properties is possible through application of method of industrial crossing of cattle of Domestic Simmental breed with French fattening breeds which are characterized by extraordinary quality of carcass and meat. In crosses of F1 generation, in this way the heterosis effect would be utilized through non-additive gene effect (for properties with low heritability), but also the effect of complementarity through the additive gene effect which is more important in this case considering that stated properties have medium to high heritability values - $h^2$.

In this paper, results of the research of sensory and technological quality of meat from Domestic Simmental breed and its crosses of F1 generation with Charolais and Limousin are presented.

MATERIAL AND METHODS

Investigation of sensory and technological meat properties was realized on samples of musculus longissimus dorsi (MLD) from the region of 9th to 11th rib. Total of 96 samples were analyzed, 32 from each genotype cattle group:

1) genotype G1: Domestic Simmental breed as control group (DS)
2) genotype G2: crosses of F1 generation, Domestic Simmental breed × Limousin (DS × Li)
3) genotype G3: crosses of F1 generation, Domestic Simmental breed × Charolais (DS × Ch)

In this research Domestic Simmental breed was used as maternal and Limousin and Charolais as paternal breeds.

The experimental cattle (male) were housed in free system, fed concentrated feed, hay and maize silage to the certain degree of fattening and approximate body mass of 600 kg, and following slaughtering three rib cut from the left carcass side was sampled for investigation.
Sensory evaluation of color, marbling and consistency of meat was conducted on caudal side of fresh cut of the 11th rib in controlled-laboratory conditions and with the help of group/committee in order to reduce the subjectivity of the evaluation. Evaluation of color (purple red-5 to light red-1) and marbling (devoid-1 to abundant-5) was done according to established linear evaluation scores, awarding points from 1 to 5, whereas the consistency of meat was evaluated using points from 1 to 3 (coarse-1 to fine-3) according to presence and distribution of binding tissue within the muscle.

For analysis of chemical composition (1) and technological properties (2) representative samples of central MLD were used (N=96), weighing approx. 150g from the region of 11th rib.

1) Samples for chemical analysis were adequately chopped and mixed in order to determine water content (%) (JUS ISO 1442, 1998), fat content (%) using the extraction method according to Soxhlet (JUS ISO1444, 1998), protein content – indirectly, by determining the nitrogen content using method according to Kjeldahl (JUS ISO 937, 1992), content of mineral substances (%) – by method of drying and burning on temperature of 550°C (JUS ISO 936, 1999).

2) pH value was determined using pH meter from water extract of meat (JUS ISO 2917, 2004): pigment content using methods (IS-LDM-53): a) according to Hart; and b) according to Horsney (modified by Möhler); water holding ability by method of centrifuge (IS-LDM-55); tenderness-softness of meat, instrumentally (IS-LDM-65), using the apparatus according to Wolotkewitsch; cooking loss by standard method of cooking.

Processing of experimental data of the research was realized using statistical program StatSoft.Inc (1995), Statistica for Windows. Main parameters of descriptive statistics were calculated: mean value, standard deviation, variation coefficient, minimal and maximal values. Statistical significance of the effect of genotype on observed properties was determined by variance analysis, whereas the t-test was used for testing of significance of differences between three genotypes using levels of significance of 0.05 and 0.01.

RESULTS AND DISCUSSION

The effect of genotype on sensory meat properties

Sensory meat properties: color, marbling and structure represent properties of extreme significance for the quality of meat and its demand on the market. In their expression, beside the genotype, there are also their mutual relations. Also, these properties can reflect on some other technological meat traits.

According to table 1, color of MLD in heads of Domestic Spotted breed was scored as medium-red intensive, whereas the color of crosses had lighter nuances of red. Aleksić et al. (1998) also established significant effect of genotype (p<0.05) on meat color, whereas in research by Chambaz et al. (2003),
contrary to what is established in this paper, Charolais had more favorable score for color (lighter meat) than Limousin.

Table 1. Sensory and technological properties of beef from different genotypes

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Domestic spotted (N=32)</th>
<th>DS × Limousin (N=32)</th>
<th>DS× Charolais (N=32)</th>
<th>F</th>
<th>t - test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensory properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Properties</strong></td>
<td><strong>Mean SD CV Min Max</strong></td>
<td><strong>Mean SD CV Min Max</strong></td>
<td><strong>Mean SD CV Min Max</strong></td>
<td><strong>Mean SD CV Min Max</strong></td>
<td><strong>Mean SD CV Min Max</strong></td>
</tr>
<tr>
<td>Colour</td>
<td>2.9 0.7 24.0 2.00 4.00 3.60 0.5 14</td>
<td>3.00 4.00 3.3 0.6 18.0</td>
<td>2.00 4.00 3.0 0.5 17.0</td>
<td>2.00 3.50</td>
<td>** ** ** NS</td>
</tr>
<tr>
<td>Marbling</td>
<td>2.8 0.7 26.0 1.00 5.00 2.40 0.4 15</td>
<td>2.00 3.00 2.5 0.4 17.0</td>
<td>2.00 3.50</td>
<td>** ** ** NS</td>
<td></td>
</tr>
<tr>
<td>Consistency</td>
<td>2.53 0.38 15.0 2.00 3.00 2.84 0.24 8.28</td>
<td>2.50 3.00 2.78 0.25 9.06</td>
<td>2.50 3.00</td>
<td>** ** ** NS</td>
<td></td>
</tr>
<tr>
<td><strong>Technological properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Properties</strong></td>
<td><strong>ξ S CV Min Max ξ S CV Min Max ξ S CV Min Max ξ S CV Min Max F</strong></td>
<td>G1 G2 G3 G2 G3 G3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH4a</td>
<td>5.61 0.1 5.41 5.77 5.59 0.1 2.3</td>
<td>5.33 5.82 5.56 0.1 1.7</td>
<td>5.4 5.7</td>
<td>NS NS NS NS</td>
<td></td>
</tr>
<tr>
<td>CL %</td>
<td>39 3.7 31.4 44.7 38 3.6 9.4</td>
<td>28.6 42.5 37.1 3.6 9.7</td>
<td>30.4 46.7</td>
<td>NS NS NS NS</td>
<td></td>
</tr>
<tr>
<td>WHC ml</td>
<td>9.7 1.2 12 8.2 12.2 9.08 1.9</td>
<td>21 2.9 13 9.59 1.4</td>
<td>14</td>
<td>7.2 13 NS</td>
<td></td>
</tr>
<tr>
<td>FD µm</td>
<td>62.9 9.4 14 44.5 81.7 57.4 11</td>
<td>19 44.4 76.9 59.6 13</td>
<td>22 40.4 82.8 NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF kg</td>
<td>8.49 1.82 21.4 5.64 11.82 7.05</td>
<td>2.31 32.7 3.89 12.20 7.69</td>
<td>2.43 31.6 2.68 13.05 NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIHO</td>
<td>102 23.8 53.04 32.6 79.69 18</td>
<td>1</td>
<td>22.8 42.84 107.1 83.61 18</td>
<td>22.7 57.80 129.1 ** ** ** NS</td>
<td></td>
</tr>
<tr>
<td>PIHA</td>
<td>1.99 0.42 21.1 1.12 2.72 1.63</td>
<td>0.36 22.1 0.86 2.14</td>
<td>1.69 0.34 19.8 1.16 2.36 ** ** ** NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water %</td>
<td>74.9 0.7 73.4 76.1 74.7</td>
<td>0.9 1.2 72.2 75.9 74.6</td>
<td>0.6 0.8 73.3 75.4 NS NS NS NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat %</td>
<td>1.39 0.5 36.0 0.54 2.29</td>
<td>1.51 0.7 44 0.52 3.19</td>
<td>1.59 1.1 66</td>
<td>0.42 5.37 NS NS</td>
<td></td>
</tr>
<tr>
<td>Protein %</td>
<td>22.7 0.6 2.80 21.6 23.9</td>
<td>22.8 1 4.4 20.4 24.4 22.8</td>
<td>0.8 3.4 20.3 24.2 NS NS NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minerals %</td>
<td>1.08 0.06 9.5 1.96</td>
<td>1.19 1.08 0.06 5.44</td>
<td>0.99 1.22 1.06 0.05 4.36</td>
<td>0.95 1.16 NS NS</td>
<td></td>
</tr>
</tbody>
</table>

Consumers often relate the presence of intermuscular fat in muscle tissue with taste of meat which is why this property is important for the buyer. Moderate marbling of meat is desirable because of covering of muscle fibers to achieve batter succulence and taste of thermally treated meat. Poor marbling can cause dry and tasteless meat, whereas the excess of fat does not contribute proportionally to taste of meat (Lawrie, 1999). Marbling was lowest in Limousin crosses (2.36/5), slightly higher in Charolais crosses (2.45/5), and most expressed in Domestic Simmental breed (2.80/5). The effect of genotype was significant at the level of p<0.01, with very significant differences between Domestic breed and crosses with Limousin (p<0.01) and Charolais (p<0.05).
Poor marbling of crosses could be explained by fact that French fattening breeds have lower genetic potential for storing of fat in deposit, contrary to most of other breeds. In research by Dhuyvetter et al. (1985), difference in score for marbling of meat from Charolais and Limousin was similar (4.93 vs. 4.89), like in results presented here, whereas Aleksić et al. (1998) established the most expressed marbling in Limousin crosses (4.90), and the least expressed in Charolais crosses (4.50), and no significant effect of genotype on this trait was established.

In regard to consistency, the highest average score (2.84/3) was established in meat from Limousin crosses which corresponds to description of the finest consistency of muscle bundles. Meat from Domestic Simmental cattle had the lowest score for consistency (2.53/3), with significance of differences at the level of p<0.01 in relation to meat from crosses. Contrary to our research, Aleksić et al. (1998) did not confirm the significant effect of the genotype on consistency of meat which was scored the highest in Limousin crosses (4.67/5), followed by Charolais crosses (4.52/5) and Domestic Simmental breed (4.31/5).

**The effect of genotype on technological meat properties**

Technological properties of meat, pH value, water holding capacity and cooking loss represent important parameters of its edibility and capacity for industrial processing.

The pH value of meat, as parameter of meat quality, is very important since it influences directly or indirectly other meat properties such as: water holding ability, color, taste, tenderness, sustainability, etc. (Hofmann, 1986). In relation to whether the pH value of meat is below or above the optimum, certain undesirable changes in technological properties and appearance of meat in the form of so called PSE (pale, soft and exudative) or DFD (dark, firm dry) meat can occur. Desirable pH\textsubscript{24} values were determined for all three genotypes. Significance of differences was present only between Domestic Simmental breed and Charolais crosses at the level of p<0.05.

However, in research of Chambaz et al. (2003) pH\textsubscript{48} in Simmental breed of 5.57 deviated (p<0.01) from the same value established in meat from Limousin (pH=5.50) and Charolais (pH=5.51).

Water holding capacity (WHC) is a very important technological property because of the effect on appearance of meat prior to cooking, during cooking and also effect on succulence during mastication. WHC determined in Limousin crosses (9.08 ml) was without significant statistical differences in relation to Charolais crosses (9.59 ml) and Domestic Simmental breed (9.70 ml). In research by Renand et al. (1985) also no statistically significant differences between studied genotypes in relation to water binding ability of MLD were established.

The greatest loss in thermal processing – cooking (CL) was established in heads of Domestic Simmental breed (38.99%), followed by Charolais crosses (38.02%) and the lowest in Limousin crosses (37.07%). The effect of genotype
on cooking loss showed no statistical significance of differences between genotypes. These values were slightly higher (different temperature regimes in processing), but also in regard to genotype differences are in accordance with results obtained by Chambaz et. al. (2003) who established that cooking loss was the lowest in Limousin (14.1%) followed by Charolais (15.8%) and Simmental breed (17.1%), where, however, significant difference at the level of \( p < 0.01 \) was demonstrated. Although differences between genotypes had no statistical significance, and considering the low content of fat in meat (<2%), it can be concluded that all genotypes in the trial realized average and favorable losses during heat treatment.

Diameter of muscle fiber (FD) differs between species, breeds, genders as well as certain muscles from the same organism, and in cattle it varies within the interval from 13 to 73 \( \mu \text{m} \). Although in practice the accepted opinion is that meat deriving from muscle fibers of greater diameter is less tender, results of certain studies (Siedemann et al., 1988; Crouse et al., 1991; Maltin et al., 1998) did not confirm significant correlation between the size of fibres and sensory meat properties. Contrary to results presented in table 1, Aleksić et al. (1998) established considerable effect of genotype (\( p < 0.01 \)) on diameter of muscle fiber deriving from MLD. Diameters of muscle fibred of 49.88 \( \mu \text{m} \), 45.30 \( \mu \text{m} \) and 44.82 \( \mu \text{m} \) for Domestic Simmental breed, Charolais crosses and Limousin crosses, respectively, are considerably lower than those established here.

Meat tenderness depends on marbling, post mortalm maturation of meat and activity of calpastatin enzyme (role in post mortem proteolysis). They all together are under the influence of genotype (Wulf, 1996). Tenderness of meat, determined by shear force (SF), was statistically significantly better (\( p < 0.05 \)) in Limousin crosses (7.05 kg) compared to Domestic Simmental breed (8.49 kg). Gregory et al. (1994) established lower values of SF in Charolais crosses compared to Limousin crosses, which deviates from genotype differences established here and results obtained by Aleksić et al. (1998) where values of this force were considerably lower: 5.10 kg, 5.68 kg and 6.62 kg for crosses with Limousin, with Charolais and Domestic Simmental breed, respectively. This can be explained by lower diameter of muscle fibers and greater presence of IMF which was also investigated in trail of mentioned authors. However, established average values of fat content (<3.0%) do not correspond to recommendations stated by certain authors (Savell and Cross, 1988) in sense of improvement of technological quality of meat, such as tenderness, WHC, color, etc. In meat samples slightly higher content of intramuscular fat is present, although the score for marbling was lower. This discord can be explained by finer
distribution of fat drops in muscle tissue of crosses, whereas in meat of Domestic Simmental breed they are grouped in form of small islands, giving visual impression of more fat.

In regard to pigment content (PC), established by method according to Hart (PCHA) and Horsney (PCHO), statistically significant differences are present (p<0.01) between Limousin and Charolais crosses (83.6 and 79.6 ppm) and Domestic Simmental breed (101.9 ppm). Differences in pigment content in meat were in accordance with sensory determined color of meat, where meat from Domestic Simmental breed was scored as darker compared to meat from crosses. Chambaz et al. (2003) established significant and negative correlation between pigment content and meat color (r= -0.68; p<0.01) where the highest pigment content was established in Simmental breed (1.40 mg/kg), but meat from Limousin had higher pigment content (1.27 mg/kg) than meat from Charolais (1.21 mg/kg).

CONCLUSIONS

Based on realized research it can be concluded that in crosses of F1 generation of Domestic Simmental breed and French fattening breeds certain improvements were achieved, primarily in sensory properties of meat. Colour of meat from crosses was lighter and more desirable compared to Domestic Simmental breed. Consistency of meat was also considerably improved, whereas the marbling of meat from crosses, in spite of higher fat content, was scored low (probably thanks to fine distribution) which is in favor of the edible and technological quality of meat. Technological meat properties, contrary to expectations, mainly showed no significant differences (except pH, shear force and pigment content), although in meat from crosses higher content of protein, better water binding ability, lower cooking losses and better tenderness of meat were established.

In general, by comparison of values of parameters of sensory and technological properties of meat from studied genotypes, the most desirable properties of investigated quality of meat was realized by crosses of Domestic Simmental breed with Limousin.

REFERENCES


