

EFFECTS OF CROSSING DOMESTIC SIMMENTAL WITH CHAROLAIS AND LIMOUSIN BREEDS ON CARCASS AND MEAT QUALITY

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Abstract

This paper presents the results of a study on the effects of crossing domestic Simmental with French fattening breeds, Charolais and Limousin, on carcass and meat quality. The quality of carcasses from domestic Simmental cattle and its crosses ($N = 30$) was analysed by total dissection for the proportion of retail cuts in the carcass and carcass tissues. Traits of meat sensory and technological quality were investigated using standard methods on a total of 96 carcasses. The results showed that crossing did not have a significant effect on the proportion of retail cuts except the proportion of tenderloin steak, which was significantly higher ($P < 0.01$) in crosses with Charolais (1.87%) and Limousin (1.85%) compared to the domestic Simmental breed (1.38%). However, highly significant differences ($P < 0.01$) were established for the level of tissue content in the whole carcass. The highest proportion of muscle tissue (81.5%) was determined in carcasses obtained from Limousin crosses, whereas the highest content of bone (16.45%) and fat tissue (5.26%) was recorded in carcasses of domestic Simmentals. Crossing had positive effects on the sensory quality of meat except for marbling, which scored very low in the crosses. In general, comparison of the parameters of sensory and technological quality of meat from the studied genotypes showed that the most desirable quality properties of the meat were obtained from crosses of domestic Simmental and Limousin breeds.

Key words: crossing, carcass quality, retail cuts, meat quality

Quality of beef carcasses can be considered, among other things, from the standpoint of the proportion of retail cuts and carcass tissues. The most desirable cuts (tenderloin steak, round, loin, back and shoulder) are characterized by a high proportion of muscle tissue and a low proportion of connective tissue, which is in accordance with their nutritional significance. Also, the economic impact is of great importance for cattle production and meat processing industry because the market price of each retail cut is commensurate with its quality and weight. A higher profit is realized per unit (i.e. carcass) with a higher proportion of more valuable carcass parts. Therefore,

efforts by the selection experts to favour genotypes characterized by a higher proportion of high quality carcass parts and higher proportion of muscle tissue are well justified.

The definition of meat quality is very complex and can be considered from several different aspects (technological, nutritional, health, etc.), where consumer demands have a very important role especially in regard to fat content, colour, marbling and meat tenderness. Studies on the consumer preferences in Serbia (Ostojić et al., 2005) revealed that a decisive role in selection of beef is played by meat colour, followed by marbling and tenderness. The average consumer in Serbia prefers young beef with lighter nuances of red and medium level of marbling. These properties are of great importance in regard to the quality of meat and its demand on the market. In addition to genotype, their mutual relations can have an important role in the expression of these properties. Also, these properties can reflect some technological traits of meat. Meat pH value, water holding capacity and cooking loss are important indicators of its edibility and suitability for industrial processing.

In Serbia, production and consumption of beef has been showing a negative trend for a long time, taking a position behind somewhat less expensive pork and poultry meat. Data from the Bureau of Statistics of the Republic of Serbia indicate that in 2008, 491,000 head of cattle were slaughtered (of which 216,000 were fattening young cattle) and 98,676 t of beef were produced, i.e. 201 kg of meat per animal with average dressing percentage of 54–55%. These statistics show the need for improvement of carcass and meat quality traits in the present fattening material, i.e. in domestic Simmental cattle from which most (70%) of the meat on the market is obtained.

Carcass and meat quality shows variation as a result of numerous (pre-slaughter and post-slaughter) factors. The effect of breed, i.e. genetic factors, can be considered as the decisive factor (Chambaz et al., 2003; Adamczyk et al., 2004; Bilik et al., 2006). These properties can be improved relatively quickly and efficiently by applying methods of commercial crossing of domestic Simmental cattle with French fattening breeds, characterized by exceptional carcass and meat quality. In F1 generation crosses the heterosis effect would be exploited by way of non-additive gene effect (for traits with low h^2) but also the complementary effect through additive gene effect, which in this case is more important considering that these traits have medium to high heritability values. Fries and Ruvinsky (1999) found heritability values to range from 0.37 for proportion of bones to 0.71 for proportion of meat in the carcass. Similarly, Marshall (1994) concluded that potential contribution of crossbreeding to the improvement of carcass quality is primarily contribution of the genetic complementary effect and less of heterosis.

Numerous authors (Dhuyvetter et al., 1985; Renand et al., 2001; Gregory et al., 1994) studied the effect of genotype, as well as the results of crossing domestic breeds with French fattening breeds for the purpose of improving parameters of sensory and technological meat quality. Chambaz et al. (2003) established significant differences in sensory and technological meat properties between investigated breeds (Charolais, Limousin, Simmental and Angus) fattened to achieve the equal content of intramuscular fat (3.25%). In their research a significant effect of genotype on

meat colour, pigment content, pH and cooking loss was determined, and the worst properties were recorded for meat obtained from Simmental cattle.

This study investigated the effect of commercial crossing of the domestic Simmental breed with French fattening breeds on the proportion of retail cuts, on the content of carcass tissues, as well as on the properties of sensory and technological quality of meat.

Given the above, we tested the hypothesis that the use of commercial crossing of the domestic Simmental breed with French fattening breeds will have a positive effect on carcass and meat quality of F1 animals.

The aim of the study is to examine differences in the growth rates, carcass and meat quality of different genotypes, indicate their respective advantages and disadvantages, and ultimately determine the potential genotype with the most desirable characteristics in terms of quality and meat yield. After that, the commercial crossing would involve 20–25% of females of the domestic population. These measures have the ultimate aim of increasing beef consumption in Serbia and its exports to the demanding EU market, which would bring significant economic effects and increase the use of land and other resources in Serbia.

Material and methods

The investigation was done at an experimental cattle farm of the Institute for Animal Husbandry in Belgrade, Serbia. Females of the dual-purpose domestic Simmental breed, with average withers height of 133 cm and average body weight of 700 kg, were used as the maternal component for commercial crossbreeding with Charolais and Limousin sires positively tested for easy calving, high yield, and good carcass and meat quality. The same cows were used to form the control group: young cattle of the domestic Simmental breed inseminated with Fleckvieh bulls. All cows were artificially inseminated at the age of 16–22 months. After calving, until four months of age, all suckling calves were kept in the loose housing system with their mothers (cow-calf system) and they consumed concentrate and hay *ad libitum*. Young male cattle at 155–165 days of age and 175–220 kg body weight were included in the experiment. They were housed in the free system with *ad libitum* feeding and watering regime (troughs), which made food and water available all the time.

The carcass and meat quality was analysed using chilled carcasses of cattle from three genotype groups (G1-G3): G1 – young cattle of the domestic Simmental breed (DS) as a control group; G2 – crosses of F1 DS × Limousin; and G3 – crosses of F1 DS × Charolais. The investigation covered a total of 96 carcasses, of which 30 were totally dissected. Thus, analysis of meat quality was done on 32 samples from each genotype group, whereas carcass quality was investigated in 10 carcasses from each genotype group.

Cutting of carcasses into retail cuts and total dissection were performed according to the Rulebook on quality of slaughter livestock, birds and wild game. Total dissection was done on left carcass sides that weighed 169 kg on average.

Table 1. Feeding regime during the fattening

Feeds	Body weight (kg)		
	to 220	from 220 to 300	over 300
Concentrate mixture composition (%)			
Dried maize	48.60	65.70	
Maize grain silage			60.00
Wheat middlings	15.00	10.00	15.30
Sunflower meal	20.00	16.20	21.00
Soybean meal	13.00	5.00	
Dicalcium phosphate	0.30	0.10	0.20
Calcium carbonate	1.60	1.50	1.50
Salt	0.50	0.50	1.00
Premix	1.00	1.00	1.00
Mean amount (kg/day)	3	5	9
Mean amount (kg/100 kg body weight)	1.50	1.90	1.50
Whole plant maize silage			
Mean amount (kg/day)	5.00	10.00	15.00
Mean amount (kg/100 kg body weight)	2.50	3.00	2.50
Medium quality hay			
Mean amount (kg/day)	1.00	2.00	0.00
Mean amount (kg/100 kg body weight)	0.50	0.75	0

Sensory evaluation of meat colour, marbling and consistency was conducted on the caudal side of freshly cut 11th rib in controlled-laboratory conditions by a professional board (consisting of five evaluators) in order to avoid the subjectivity of the score. Evaluation of colour (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 the presence and distribution of bound tissue within the muscle.

For analysis of chemical composition (1) and technological properties (2), representative samples of central *musculus longissimus dorsi* (MLD) were used (N = 96), which weighed approx. 150 g and were taken from the region of the 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 the method according to Kjeldahl (JUS ISO 937, 1992); and content of mineral substances (%) – by the method of drying and burning at 550°C (JUS ISO 936, 1999),

2) pH₂₄ value was determined using a 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 capacity by the method of centrifugation (IS-LDM-55); tenderness of meat instrumentally (IS-

LDM-65), using the apparatus according to Wolotkewitsch; and cooking loss by the standard method of cooking.

The experimental data were processed using Statistica for Windows (StatSoft Inc., 2007). Main parameters of descriptive statistics were calculated: mean value, standard deviation and variation coefficient. Statistical significance of the effect of genotype on the observed properties was determined by variance analysis, whereas the t-test was used for testing significance of differences between three genotypes using 0.05 and 0.01 levels of significance.

Results

The effect of crossing on carcass quality

Before disclosing the results of dissection, it is important to note that the experimental crosses at the end of fattening (fattening lasted to approx. 600 kg body weight) had considerably lower average age (445 days) compared to domestic Simmental cattle (477 days). The data concerning the effect of crossing on the proportion of carcass retail cuts and tissue content are presented in Table 2.

Based on analysis of data obtained by carcass cutting, it was established that crossing had not led to statistically significant differences in the proportions of retail cuts in the carcass. One exception was the proportion of tenderloin steak which was significantly higher ($P < 0.01$) in Charolais and Limousin crosses, thus increasing the quality and economic value of the carcass. Also, a significant increase ($P < 0.01$) in the proportion of muscle tissue in the round of crosses was realized compared to the rounds of domestic Simmentals, in which a significantly higher ($P < 0.01$) proportion of bones was recorded.

Finally, the analysis of data obtained by total dissection of carcasses showed highly significant ($P < 0.01$) differences in the content of muscle and bone tissue between the investigated genotypes. The highest total content of muscle tissue was found in the carcasses of Limousin crosses (81.5%), whereas the highest total bone content was recorded in the carcasses of Simmentals (16.45%).

The effect of genotype on sensory and technological meat properties

Based on the data for sensory and technological meat properties presented in Table 3, it is concluded that certain improvements were realized in F1 crosses of domestic Simmentals and French fattening breeds, primarily in regard to meat sensory properties. Colour of meat obtained from the crosses had more desirable, lighter nuances which corresponded to lower pigment content compared to the domestic breed. Structure of meat also improved significantly, while marbling of meat from the crosses, in spite of higher fat content, received low scores.

Contrary to expectations, technological meat properties mostly showed no significant differences (with the exception of pH, shear force and pigment content), although higher protein content was determined in the meat of crossbreds in addition to better water holding capacity, lower cooking loss and better tenderness of meat.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Tissue content in retail cuts (%)													
(N = 30)													
Round	29.8	1.3	4.37	29	1.63	5.63	28.8	1.88	6.53	ns	ns	ns	ns
Muscle	84.1	2.3	2.74	87.3	1.84	2.11	86.4	1.37	1.58	**	**	**	ns
Bone	12.9	1.67	12.9	11.1	1.2	10.7	11.2	1.05	9.42	**	**	**	ns
Fat	2.61	1.17	45.0	1.43	1.08	75.6	2.25	1.22	54.2	ns	*	ns	ns
Connective tissue	0.44	0.46	104.	0.20	0.16	80.8	0.19	0.20	102.	ns	ns	ns	ns
Tenderloin	1.38	0.14	10.2	1.85	0.41	22.0	1.87	0.27	14.5	**	**	**	ns
Loin	4.65	0.46	9.79	4.57	0.68	14.8	4.69	0.36	7.68	ns	ns	ns	ns
Muscle	75.14	3.13	4.16	75.37	5.95	7.90	75.10	5.78	7.69	ns	ns	ns	ns
Bone	21.60	3.84	17.7	19.73	6.25	31.7	19.55	4.71	24.0	ns	ns	ns	ns
Fat	2.28	0.97	42.7	4.20	2.07	49.2	4.58	2.58	56.2	*	*	*	ns
Connective tissue	0.99	0.62	62.6	0.71	0.36	51.1	0.76	0.81	106.	ns	ns	ns	ns
Back	5.34	0.63	11.7	5.54	0.66	11.9	5.27	0.84	16.0	ns	ns	ns	ns
Muscle	72.59	7.88	10.8	75.23	5.87	7.81	74.04	5.19	7.02	ns	ns	ns	ns
Bone	17.90	2.94	16.4	17.17	3.50	20.3	18.84	3.78	20.0	ns	ns	ns	ns
Fat	7.83	5.32	67.8	6.13	3.67	59.8	5.70	1.84	32.2	ns	ns	ns	ns
Connective tissue	1.05	0.75	72.0	0.57	0.32	56.7	0.72	0.35	48.8	ns	ns	ns	ns
Shoulder	13.97	0.94	6.73	12.90	1.07	8.32	13.50	0.78	5.77	*	*	ns	ns
Muscle	82.91	2.58	3.12	84.94	1.27	1.49	84.93	3.31	3.90	ns	*	ns	ns
Bone	14.73	1.74	11.7	13.73	1.33	9.69	13.69	2.85	20.8	ns	ns	ns	ns
Fat	1.63	1.24	76.0	0.98	0.94	96.3	1.04	1.01	97.0	ns	ns	ns	ns
Connective tissue	0.74	0.52	70.3	0.35	0.22	64.2	0.34	0.24	71.7	*	*	ns	ns

* denotes statistically significant differences at the level of $P \leq 0.05$; ** at the level of $P \leq 0.01$; ns – at the level of $P > 0.05$.

Table 3. The effect of crossing on meat quality

Genotype	Domestic Simmental G1 (n = 32)			DS × Limousin G2 (n = 32)			DS × Charolais G3 (n = 32)			F	t test		
	x	S	CV	x	S	CV	x	S	CV		G1 G2	G1 G3	G2 G3
Sensory properties													
Colour	2.9	0.7	24.0	3.60	0.5	14	3.3	0.6	18.0	**	**	*	ns
Marbling	2.8	0.7	26.0	2.40	0.4	15	2.5	0.4	17.0	**	**	*	ns
Structure	2.53	0.38	15.0	2.84	0.24	8.28	2.78	0.25	9.06	**	**	**	ns
Technological properties:													
pH ₂₄	5.61	0.1	1.8	5.59	0.1	2.3	5.56	0.1	1.7	ns	ns	*	ns
CL (%)	39	3.7	9.4	38	3.6	9.4	37.1	3.6	9.7	ns	ns	ns	ns
WHC (ml)	9.7	1.2	12	9.08	1.9	21	9.59	1.4	14	ns	ns	ns	ns
FD (µm)	62.9	9.4	15	57.4	11	19	59.6	13	22	ns	ns	ns	ns
SF (kg)	8.49	1.82	21.4	7.05	2.31	32.7	7.69	2.43	31.6	ns	*	ns	ns
PCHO	102	23.8	23.3	79.69	18.1	22.8	83.61	18.9	22.7	**	**	**	ns
PCHA	1.99	0.42	21.1	1.63	0.36	22.1	1.69	0.34	19.8	**	**	**	ns
Water (%)	74.9	0.7	0.90	74.7	0.9	1.2	74.6	0.6	0.8	ns	ns	ns	ns
Fat (%)	1.39	0.5	36.0	1.51	0.7	44	1.59	1.1	66	ns	ns	ns	ns
Protein (%)	22.7	0.6	2.80	22.8	1.00	4.4	22.8	0.8	3.4	ns	ns	ns	ns
Minerals (%)	1.08	0.06	5.12	1.08	0.06	5.44	1.06	0.05	4.36	ns	ns	ns	ns

* Denotes statistically significant differences at the level of $P \leq 0.05$; ** at the level of $P \leq 0.01$; ns – at the level of $P > 0.05$.

pH₂₄ – pH₂₄ value; CL – cooking loss; WHC – water holding capacity; FD – muscle fibre diameter; SF – shear force; PCHO – pigment content according to Horsney; PCHA – pigment content according to Hart.

Discussion

Results of the present study investigating the effect of crossing on carcass quality are not in compliance with the findings of Medić et al. (1991) and Aleksić et al. (2001). Medić et al. (1991) stated highly significant deviations in the proportion of round in Limousin crosses (30.3%) compared to the crosses with Charolais (27.9%) and domestic Simmental animals (26.8%). Aleksić et al. (2001) established a higher proportion of loin in the carcasses of domestic Simmentals (4.69%) compared to Limousin crosses (4.12%). In keeping with the results presented in our study, Medić et al. (1991) also established the highest proportion of tenderloin steak in Charolais crosses (1.73%), followed by crosses with Limousin (1.67%) and domestic Simmental breed (1.67%).

By comparing values of parameters of sensory and technological meat quality between studied genotypes, it can be concluded that the most desirable quality prop-

erties of investigated meat were recorded in the crosses of domestic Simmental and Limousin.

Similarly to our results, Aleksić et al. (1998) established a significant effect of genotype ($P < 0.05$) on meat colour, whereas in a study by Chambaz et al. (2003), contrary to our results, Charolais had more desirable meat colour than Limousin. In the research by Dhuyvetter et al. (1985) differences in meat marbling scores between Charolais and Limousin were similar to our results (4.93 vs 4.89). Aleksić et al. (1998) established the highest expression of marbling in Limousin crosses (4.90), and the lowest in Charolais crosses (4.50) without any significant effect of genotype on this trait.

Chambaz et al. (2003) found cooking loss to be the lowest in meat from Limousin (14.1%), followed by Charolais (15.8%) and Simmental animals (17.1%), with significant differences ($P < 0.01$). In our study, differences between genotypes had no statistical significance, and considering the low content of fat in the meat ($< 2\%$), it can be concluded that all genotypes in the trial realized average and favourable losses during heat treatment.

Contrary to the results presented in Table 3, Aleksić et al. (1998) established a significant effect of genotype ($P < 0.01$) on muscle fibre diameter. The diameters of muscle fibres (49.88, 45.30 and 44.82 μm in domestic Simmentals and in crosses with Charolais and Limousin, respectively) are considerably lower compared to the values established in our study.

Gregory et al. (1994) reported lower shear force values in Charolais crosses compared to Limousin crosses, which differs from genotype differences established in our study (Table 3) and from the results obtained by Aleksić et al. (1998), who found shear force values to be considerably lower (5.10, 5.68 and 6.62 kg for crosses with Limousin, Charolais and domestic Simmental, respectively). This can be explained by the smaller diameter of muscle fibres and higher proportion of intramuscular fat, which was also investigated in the trial mentioned above.

The established average values for fat content ($< 4.5\%$) are in disagreement with the recommendations stated by some authors (Ender et al., 2000) for improvement of technological quality parameters such as tenderness, WHC, colour, etc. In meat samples obtained from the crosses, somewhat higher content of intramuscular fat was established, even though their meat had lower marbling score. This discrepancy could be attributed to the finer distribution of fat drops in the muscle tissue of the crosses, whereas in the meat derived from domestic Simmentals, fat drops are grouped in the form of small islands, giving a visual impression of more fat.

Chambaz et al. (2003) established a significant and negative correlation between pigment content and meat colour ($r = -0.68$; $P < 0.01$). The highest pigment content was, like in our study, determined in the Simmental breed (1.40 mg/kg) but, contrary to our results (Table 3), Limousin meat had a higher pigment content (1.27 mg/kg) than Charolais meat (1.21 mg/kg).

The absence of significant differences in the proportion of retail cuts in carcasses of F_1 generation crosses can be explained by the fact that at slaughtering, the crosses, even those with higher body weights were significantly younger than domestic Simmental cattle. It is known that rump and loin carcass parts develop at a later age;

therefore, considering the genetic potential of the breeds used, it is recommended that crosses should be slaughtered at older age compared to purebreds from which they are derived. In that case, more significant differences can be expected in the proportion of retail cuts, but also somewhat higher fat content of meat which could reflect positively on the eating quality of meat.

In conclusion, the highest meat content of carcasses was achieved in Limousin crosses, and the highest contents of bone, fat and connective tissue in the domestic Simmental, while Charolais crosses had the highest proportion of tenderloin in the carcass. In terms of meat quality, the most desirable properties among the observed genotypes were found in the Limousin crosses. Between the quality and quantity of meat, but also within the complex traits of meat, there are antagonistic relations that hamper the efforts of selection experts to create an ideal breed that would suit all the requirements of producers and consumers of meat. However, pooling the positive performance of domestic Simmental and French beef cattle enables the animals obtained from these crosses to be fattened up to the final weight of 600 kg while retaining the characteristics of quality beef that meet the demands of modern consumers.

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Accepted for printing 15 II 2011

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Wpływ krzyżowania krajowych Simentali z rasami Charolaise i Limousine na jakość tuszy i mięsa

STRESZCZENIE

Artykuł przedstawia wyniki badań nad wpływem krzyżowania serbskich Simentali z francuskimi rasami mięsnymi Charolaise i Limousine na jakość tuszy i mięsa. Jakość tusz pochodzących od krajowego bydła simentalskiego i jego mieszańców (N=30) analizowano w czasie całkowitej dysekcji pod kątem udziału elementów detalicznych tuszy i tkanek. Cechy sensorycznej i technologicznej jakości mięsa badano standardowymi metodami na 96 tuszach. Wyniki badań wskazują, że krzyżowanie nie miało istotnego wpływu na udział elementów detalicznych z wyjątkiem udziału polędwicy, który był istotnie wyższy ($P<0,01$) u mieszańców z rasami Charolaise (1,87%) i Limousine (1,85%) w porównaniu do krajowej rasy simentalskiej (1,38%). Wysoko istotne różnice ($P<0,01$) zanotowano jednak dla poziomu zawartości tkanek w całej tuszy. Najwyższy udział tkanki mięśniowej (81,5%) stwierdzono w tuszach uzyskanych od mieszańców rasy Limousine, natomiast najwyższą zawartość kości (16,45%) i tkanki tłuszczowej (5,26%) zanotowano w tuszach krajowych Simentali. Krzyżowanie miało pozytywny wpływ na sensoryczną jakość mięsa z wyjątkiem marmurkowatości, która u mieszańców była bardzo niska. Porównanie parametrów sensorycznej i technologicznej jakości mięsa pochodzącego od badanych genotypów pokazało, że najbardziej pożądaną cechy jakościowe mięsa uzyskano u mieszańców krajowego Simentala i rasy Limousine.