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The chemical compositions and fatty acid profile of the longissimus dorsi muscle in young Simmental bulls

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ABSTRACT

The objective of this paper was to analyse the carcass characteristics (live weight at slaughter, hot and cold carcass weight, fat weight and fat ratio in cold carcass weight), chemical composition and fatty acid profile of the Simmental cattle longissimus dorsi muscle (MLD). The experiment was carried out on 20 young bulls (sons of sires in progeny testing for meat quality). The average live weight at slaughter (LWS) was 555 ± 12.47 kg, hot carcass weight (HCW) 332.6 ± 7.88 kg, cold carcass weight (CCW) 331.3 ± 8.43 kg, fat weight 15.9 ± 0.81 kg, fat ratio in CCW was 4.89 ± 0.23%. The average chemical composition of MLD was as follows: dry matter 24.84 ± 0.17%, water 75.16 ± 0.17%, protein 20.46 ± 0.26%, intramuscular fat 3.28 ± 0.06% and ash 1.11 ± 0.01%. Linear correlation was calculated for all parameters and high correlations were found between LWS, HCW and CCW, as expected, but there was no significant effect of LWS on the chemical composition of the longissimus dorsi muscle. Intramuscular fat (IMF) consisted on average of 48.04 ± 0.59%, 47.58 ± 0.71% and 4.16 ± 0.25% of total fatty acids (FA) as saturated fatty acids (SFA), mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA), respectively. The PUFA/SFA ratio for beef was low, at around 0.1, similar to that reported by other authors. As expected, the level of MUFA correlated highly with the Δ9-desaturase (18) index (r = 0.84) and elongation index (r = 0.54). Statistically significant correlations between specific fatty acids, LWS, fat and IMF were generally weak. The percentages found of SFA and PUFA, as well as the PUFA/SFA ratio, were in accordance with results reported by other authors but still unfavourable for human health. To improve the unfavourable characteristics of beef, further study should include genetic parameters that affect the FA composition of beef beside the other factors mentioned above.

Key words: Simmental cattle, longissimus dorsi, chemical composition, fatty acid

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Introduction

The requirements of the meat market today are focused on the composition of dietary fats, and in particular saturated fats, due to their impact on human health. It is well known that the composition of dietary fats may promote the pathogenesis of many diseases, including cardiovascular, inflammatory and autoimmune diseases (SIMOPOULOS, 2004). From this point of view there is a great emphasis on modifying the fat composition of the human diet, such as reducing saturated fatty acids (SFA) in favour of polyunsaturated fatty acids (PUFA). The correlation of SFA and PUFA values is given by the PUFA/SFA (P/S) ratio. The minimum P/S ratio set for human nutrition is at least 0.45 or higher (ZAPLETAL et al., 2009). Apart for reducing the saturated fat content of the diet, nutritional guidelines recommend increasing the intake of *n*-3 PUFA's relative to *n* -6 PUFA's to achieve a *n*-6/*n*-3 ratio close to 4.0 (SANTOS-SILVA et al., 2002; WEBB and O'NEILL, 2008). Meat producers have responded by reducing the fat content in red meat by selective breeding (ELI'AS CALLES et al., 2000; HUERTA-LEIDENZ et al., 1993) and the introduction of modified feeding practices (FRENCH et al., 2001; HORNICK et al., 1998).

Simmental cattle (SC) are the most common dual-purpose breed in Croatia that accounts for up to 65 % of the overall cattle population (Croatian Agriculture Agency annual report, CAA 2010). A few papers have reported the fatty acid profile of dual-purpose Simmental breed and breeds of Simmental origin (PIASENTIER et al., 2009; BARTON et al., 2010). Meat quality is considered to be a very important breeding goal in Croatia. Therefore, the objective of this paper was to analyse the carcass characteristics (live weight at slaughter, hot and cold carcass weight, fat weight and fat ratio in cold carcass weight), the chemical composition and fatty acid profile of the longissimus dorsi muscle in young Simmental bulls, sons of sires in a progeny test for meat quality, and compare them with similar results for the same and different breeds of cattle.

Materials and methods

Animals and experimental design. The experiment was carried out on 20 young bulls of Simmental breed sons of sires in a progeny test for meat quality. The experimental animals were loose-housed from the age of 120 days (after a 45 days preparation period) until slaughter. They were fed by concentrate and hay (60% energy from concentrate diets) and water was available ad libitum.

The animals fasted for 12 hours before slaughter. Data about the age at slaughter (all animals were approximately 420 days), live weight at slaughter (LWS) and hot carcass weight (HCW) were recorded on the slaughter day. After a chilling period of approximately 24 hours, samples of the longissimus dorsi muscle were collected (7^{th} - 9^{th} thoracic rib cut). Thoracic rib cuts were anatomically dissected and the share of each tissue was determined (RAKO, 1960).

Chemical composition and fatty acid profile. The moisture content was determined by drying homogenized meat samples at 105 °C to the constant weight. The nitrogen content was determined by the standard Kjeldahl procedure and expressed as protein content (nitrogen content multiplied by 6.25). The ash content was determined by burning in a laboratory furnace at a temperature of 610 °C (KRIŽANOVIĆ, 1990). The fat content was determined by extraction (petrolether) in a Soxhlet extractor. The extraction was performed by acid hydrolysis.

The fatty acids obtained were converted to the corresponding FAMEs by *trans*-esterification with a methanolic solution of potassium hydroxide (2 mol/L) (ISO 5509, 2000). The solution was shaken vigorously for about 30 s. The solution was neutralized by addition of sodium hydrogen sulphate monohydrate. After the salt had settled, 1 mL of upper phase was transferred into a 2 mL vial and analyzed (PETROVIĆ et al., 2010).

The analyses of FAME's were performed on a CP-3800 gas chromatograph (Varian, Palo Alto, USA), equipped with a flame ionization detector (FID). A fused silica capillary column DB-5.60 m x 0.25 mm x 0.25 μm (Agilent Technologies, Santa Clara, CA, USA) was used with the following temperature program: the initial temperature was 180 °C and then increased at 3 °C/min to 250 °C and held for 15 min. The carrier gas was nitrogen. The injector and detector (FID) were set at 260 °C. FAMEs were identified by comparison of their retention times with the retention times of FAMEs obtained by injection of Food Industry FAME mix (Restek, Bellafonte, PA, USA). The result of the evaluations is the content (%) of fatty acids. Indexes of Δ9-desaturase enzyme activity were calculated using formulas described by ZAPLETAL et al. (2009) and PITCHFORD et al. (2002).

Statistical Analysis. A statistical analysis was performed using STATISTICA v.10 (StatSoft.Inc, 2010, Tulsa, USA) software. The relationships between the variables were tested by means of linear correlation. The correlations were considered statistically significant if $P<0.05$.

Results

Carcass characteristics and chemical composition. The live weight at slaughter, carcass traits (hot weight, lean weight, fat weight) and the chemical composition of the longissimus dorsi muscle are summarized in Table 1.

Table 1. Mean values of live weight, carcass quality traits and chemical composition of the longissimus dorsi muscle

Trait	X	SEM
LWS (kg)	555.0	12.47
HCW (kg)	332.6	7.88
CCW (kg)	331.3	8.43
Fat (kg)	15.9	0.81
Fat ratio in CCW (%)	4.89	0.23
Longissimus dorsi composition		
Dry matter (%)	24.84	0.17
Moister (%)	75.16	0.17
IMF (%)	3.28	0.36
Protein (%)	20.46	0.26
Ash (%)	1.11	0.01

X: mean; SEM: standard error of the mean; LWS: live weight at slaughter; HCW: hot carcass weight; CCW: cold carcass weight; IMF: intramuscular fat

Linear correlation was calculated for all parameters and high correlations were found between LWS, HCW and CCW, as expected, but there was no significant effect of LWS on the chemical composition of the longissimus dorsi muscle.

Fatty acids profile. The fatty acid profile, fatty acid ratio and desaturase indexes of the longissimus dorsi muscle of bulls, fattened up to approximately 420 days, are shown in Table 2.

As expected, the level of MUFA was highly correlated with the Δ9-desaturase (18) index ($r = 0.84$; $P<0.05$) and elongation index ($r = 0.54$; $P<0.05$). The calculated variables were highly correlated to specific fatty acids: MUFA and oleic acid (C18:1n-9) ($r = 0.98$; $P<0.05$), PUFA and linoleic acid (C18:2n-6) ($r = 0.99$; $P<0.05$), desaturation (18) index and stearic acid (C18:0) ($r = -0.91$; $P<0.05$), and elongation index and palmitic acid (C16:0) ($r = -0.98$; $P<0.05$). Statistically significant correlations ($P<0.05$) between specific fatty acids, LWS, fat and IMF were generally weak.

Table 2. The fatty acid profile, fatty acid ration and desaturase indexes of the longissimis dorsi muscle

Fatty acid	X	SEM
C10:0	0.05	0.01
C12:0	0.05	0.01
C14:0	2.61	0.11
C16:0	24.73	0.45
C16:1	2.82	0.11
C17:0	1.05	0.05
C17:1	0.59	0.04
C18:0	19.47	0.52
C18:1-n9	43.18	0.78
C18:1-n7	0.86	0.13
C18:2-n6	3.62	0.19
C18:3-n3	0.16	0.03
C18:4-n3	0.33	0.03
C20:0	0.07	0.02
C20:1-n9	0.13	0.03
C20:4-n6	0.04	0.01
C20:5-n3	0.01	0.01
C22:5-n3	0.02	0.01
PUFA	4.16	0.25
MUFA	47.58	0.71
SFA	48.04	0.59
P/S	0.09	0.01
n-6/*n*-3 ratio	6.61	0.69
D9-desaturase (16) index	10.20	0.26
D9-desaturase (18) index	68.89	0.81
Elongation index	69.43	0.64

X: mean; SEM: standard error of the mean
PUFA: polyunsaturated fatty acids = C18:2-n6+C18:3-n3+C18:4-n3+C20:4-n6+C20:5-n3+C22:5-n3
MUFA: monounsaturated fatty acids = C16:1+C17:1+C18:1-n9+C18:1-n7+C20:1-n9
SFA: saturated fatty acids = C8:0 +C10:0+C12:0+C14:0+C16:0+C17:0+C18:0+C20:0
P/S = PUFA/SFA
n-6/*n*-3 ratio = (C18:2-n6+ C20:4-n6) / (C18:3-n3+C18:4-n3+C20:5-n3+C22:5-n3)
Δ9-desaturase (16) index = 100*[C16:1 / (C16:0+C16:1)]
Δ9-desaturase (18) index = 100*[C18:1n-9 / (C18:0+C18:1n-9)]
Elongation index = 100*[(C18:0+C18:1n-9) / (C16:0+C16:1+C18:0+ C18:1n-9)]

Discussion

The present study was conducted to evaluate the carcass traits, chemical characteristics and fatty acids contents of the longissimus dorsi muscle of Simmental bulls in Croatia. In the past few years there have been papers written reporting meat characteristics of the dual-purpose breed of Simmental origin (PETRIČ et al., 2005; ŠUBRT et al., 2006.; PIASENTIER et al., 2009). Our results were in accordance with those reported by other authors (ZAPLETAL et al., 2009) for Simmental cattle. The live weight recorded was 555 kg ± 12.47 which is slightly lower than found for Czech Fleckvieh, fattened to approximately same age (ZAPLETAL et al., 2009). However, young bulls had a higher average final mass (Table 1) compared to the mass recorded by ŠTOKOVIĆ (2009). The increase in the final mass shows the improvement, by means of selection, towards a higher final mass as proclaimed by the National Cattle Breeding Plan in Croatia.

The chemical composition of the longissimus dorsi muscle of SC in our study showed slightly higher IMF content (3.28 ± 0.36) in comparison to the literature records (BUREŠ et al., 2006). The IMF content of 2-5% in many countries is accepted as being ‘‘low in fat’’(SCOLLAN et al., 2006), so according to our findings Croatian Simmental beef could be classified as lean.

We found that intramuscular fat consisted on average of 48.04 ± 0.59%, 47.58 ± 0.71% and 4.16 ± 0.25% of total fatty acids as SFA, MUFA and PUFA, respectively. The PUFA/SFA ratio for beef is low, at around 0.1, similar to that reported by other authors (SCOLLAN et al., 2006). The minimum recommended value is 0.45 for human consumption and generally should be around 0.7 (RAES et al., 2003). The low values of P/S ratio for beef are quite normal, because of the hydrogenation of dietary unsaturated FA by rumen microorganisms.

Besides the P/S ratio, the focus has moved to the type of PUFA and the balance in the diet between *n*-3 and *n*-6 PUFA. The recommended ratio is less than 4 (WEBB and O’NEILL, 2008). The *n*-3 PUFA concentration is dependent on the intake of either the metabolic precursor α-linoleic acid (C18:3) or the preformed FA. It has beneficial effects on the development and progression of atherosclerosis. Higher C18:3 *n*-3 levels in meat are important because human beings are able to synthesize C20 PUFA and C22:6 *n*-3 from it (PIASENTIER et al., 2009). These FAs, together with C20:4 *n*-6, play various essential metabolic roles, such as in eicosanoid production (WOOD et al., 2008). However the *n*-3/*n*-6 PUFA ratio found in this experiment was 6.61 ± 0.69, a value slightly higher than the recommended range (4.0) and this ratio could express a risk factor for coronary heart disease.

According to SCOLLAN et al. (2006), the predominant SFA are C14:0 (myristic acid), C16:0 (palmitic acid) and C18:0 (stearic acid), which corresponds to our results. Moreover, the C16:0 made up the greatest proportion of SFA, which is in agreement

with PADRE et al. (2007) who studied steers from different genetic groups, feeding in pasture with mineral food supplementation. Similar results were found by WARREN et al. (2008) who analyzed fatty acid composition in the longissimus muscle of different breeds. NÜRNBERG et al. (2005) found that the percentage of C16:0 was significantly lower in the muscles of German Simmental bulls on a grass-based system, compared to bulls in an indoor concentrate system.

The plasma cholesterol is influenced by SFA. C12:0, C14:0 and C16:0 are hypercholesterolaemic, while C18:0 is considered as neutral in this regard (SCOLLAN et al., 2006). The ratio between C14:0 and C16:0 is in favour of C16:0 (WILLIAMSON et al., 2005). The content of C14:0 and C16:0 in our study is higher than reported for Slovenian Simmental bulls (PETRIČ et al., 2005) but lower than for Czech Fleckvieh (ZAPLETAL et al., 2009). The level of C18:0 was higher than that found in Italian Simmental (PIASENTIER et al., 2009) and Czech Fleckvieh (ZAPLETAL et al., 2009), which is not beneficial to human health. It is widely recognized that C18:0 favours cardio-vascular diseases.

The MUFA content observed was comprised mostly of C16:1 and C18:1 FA in Croatian Simmental bulls, in accordance with the results of ZAPLETAL et al. (2009). The highest MUFA component was C18:1-n9. These results can be explained by the level of hydrogenation of C18:1 in rumen, as well as the breed influence, as reported by PIASENTIER et al. (2009). A higher ratio of C18:1 in meat is considered desirable due to its hypocholesterolaemic properties. Steroyl-CoA desaturase (Δ9-desaturase) is a key enzyme in fatty acid metabolism. It is responsible for forming a double bond in Stearoyl-CoA. This is how the monounsaturated fatty acid is produced from the saturated fatty acid in mammalian adipocytes. Fatty acids from feed are reduced by microorganisms in the rumen and absorbed as saturated fatty acids. The previous action of Δ9-desaturase on substrates such as C18:0 or C16:0 reflects the fatty acid composition stored in adipocytes. The enzyme Δ9-desaturase is a candidate for genetic variation in fatty acid composition, because of its determinant role in FA oxidation. In our experiments, the scores for the Δ9-desaturase (16) index and the Δ9-desaturase (18) were similar to values found in literature for Simmental cattle (ZAPLETAL et al., 2009; BUREŠ et al., 2006; LABORDE et al., 2001). The conversion from 16 to 18 carbon atoms is presented by the elongation index. The elongation index found in our trial was 69.4 ± 0.64, which is in agreement with that found by PITCHFORD et al. (2002).

Total PUFA was slightly higher than found for Czech Fleckvieh (ZAPLETAL et al., 2009) but notably lower than values reported for Italian Simmental cattle (PIASENTIER et al., 2009).

Conclusions

The results from this study revealed the carcass characteristics, chemical composition and FA profile of the longissimus dorsi muscle of Simmental cattle in Croatia. The percentages of SFA and PUFA found, as well as the P/S ratio were in accordance with the results reported by other authors (ZAPLETAL et al., 2009; PIASENTIER et al., 2009; BUREŠ et al., 2006), but still unfavourable for human health.

Body and muscle fat are the most variable traits since they are influenced by various factors. The composition of fat in the muscles of farm animals is influenced by various factors, such as species, diet, fatness, age or body weight, gender and breed (NÜRNBERG et al., 1998). As shown in our paper and others, there is still great variability in carcass composition and meat characteristics, and further selection of those traits in cattle is needed. To improve unfavourable beef characteristics, further study should include genetic parameters that affect the FA composition of beef, besides the other factors mentioned above.

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SAŽETAK

Istraživanjem smo htjeli utvrditi osobine trupova te kemijski i masnokiselinski sastav najduljega leđnog mišića simentalske junadi. U istraživanje je bilo uključeno 20 junadi. Utvrđena je prosječna masa živih životinja 555 ± 12,47 kg, masa toplih polovica 332,6 ± 7,88 kg, masa hladnih polovica 331,3 ± 8,43 kg, masa masti 15,9 ± 0,81 kg, omjer masti i mase hladnih polovica 4,89 ± 0,23%. Prosječan kemijski sastav MLD bio je: suha tvar 24,84 ± 0,17%, voda 75,16 ± 0,17%, protein 20,46 ± 0,26%, intramuskularna mast 3,28 ± 0,06% i pepeo 1,11 ± 0,01%. Izračunali smo linearne korelacije između promatranih obilježja te su pronađene visoke korelacije između mase živih životinja, mase toplih i hladnih polovica. No nije utvrđena značajna korelacija između mase živih životinja i kemijskog sastava MLD. U intramuskularnom masnom tkivu utvrđeno je 48,04 ± 0,59%, 47,58 ± 0,71% i 4,16 ± 0,25% zasićenih (SFA), mononezasićenih (MUFA) i polinezasićenih (PUFA) masnih kiselina. Omjer PUFA/SFA je nizak i iznosi oko 0,1 što je slično istraživanjima drugih autora. Očekivano je ukupna količina MUFA u visokoj korelaciji s indeksom Δ9-desaturaze (18) (r = 0,84) i indeksom elongacije (r = 0,54). Utvrđene su slabe, iako statistički značajne korelacije između pojedinih masnih kiselina, mase živih životinja, ukupne i intramuskularne masti. Utvrđeni rezultati za SFA i PUFA, kao i P/S omjer u skladu su s rezultatima drugih autora no i dalje nepovoljni za ljudsko zdravlje.

Ključne riječi: simentalac, najduži leđni mišić, kemijski sastav, masne kiseline