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Phenotypic characteristics and heritability of m. longissimus dorsi chemical composition in Croatian Simmental bulls

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ABSTRACT

The Simmental breed is a dual purpose breed widespread in the Republic of Croatia and represents more than two thirds of the total cattle population. In this research we focused on the heritability of chemical components (dry matter, water, protein, fat and ash) in musculus longissimus dorsi (MLD) and its phenotypic characteristics. The trial comprised 698 young bulls, which were sons of 68 sires chosen for artificial insemination (AI), over a period of 13 years. Average chemical composition of MLD was as follows: dry matter 24.87 ± 0.04%, water 75.13 ± 0.04%, protein 20.63 ± 0.05%, fat (ether extract) 3.14 ± 0.06% and ash 1.10 ± 0.002%. We calculated heritability and phenotypic correlations among the chemical components and analyzed various influences for all components. All calculations were performed in SAS 8.0 (Statistical Analysis System) and Statistica 7.1 software. Phenotypic correlations between dry matter and water, protein, fat and ash were -1.00, 0.20, 0.50 and -0.20, respectively. Correlations between water and protein, fat and ash were -0.20, -0.50 and 0.20, respectively. Correlation coefficient between protein and fat was -0.75; between protein and ash -0.05 and between fat and ash -0.10. All correlations were significant ($P<0.01$) except between protein and ash. Heritability estimates for the investigated traits were: final mass 0.73; dry matter 0.60; water 0.60; protein 0.40; fat 0.30 and ash 0.36. The influence of year, season and month on chemical composition of MLD was significant ($P<0.01$). Phenotypic correlations and heritability estimates could be used for selection in order to improve the investigated traits.

Key words: Simmental cattle, musculus longissimus dorsi, chemical composition, heritability

Introduction

The Simmental breed is known as a dual purpose breed widespread in the Republic of Croatia. It represents more than two thirds (72.3%; ANONYM., 2007) of the total cattle population in Croatia. In this experiment we focused on the heritability of musculus

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longissimus dorsi (MLD) chemical components and its phenotypic characteristics. MLD was chosen because it is the largest and the longest muscle in the body (KÖNIG and LIEBICH, 2001). The chemical composition of meat affects meat quality, while proteolysis of myofibrillar proteins is considered to be the main biochemical factor contributing variation in meat tenderness (KOOHMARAIE et al., 2002). Testing sires for the chemical composition of MLD may be useful in improvement of meat quality, because proper muscle:fat ratio greatly influences the marbling score and juiciness of retail cuts. It is important to know how individual components are connected to each other. From the selection point of view it is valuable to find out how these traits are heritable. There is evidence of various influences on meat quality, such as the sire, breed, muscle fiber characteristics and others (MAHER et al., 2004). It is important to find out which factors predominantly influence the chemical composition of MLD.

In this work we investigated how the year and season of fattening influenced MLD chemical composition.

Materials and methods

The trial comprised 698 young bulls, the progeny of 68 sires over a period of 13 years (from 1993 till 2005). Sires were included in the progeny test for meat quality. Young bulls were placed in the Hrsovo test station at approximately the same age (60 days). After 15 days of accommodation and 45 days of preparation they were fattened under a controlled regime from the age of 120 days. The fattening period lasted approximately 300 days.

Young bulls were kept in a loose housing system and fed with concentrates and hay (60% energy from concentrate diets). Water was available ad libitum.

Animals fasted 12 hours before slaughtering. They were weighed twice, at the end of fattening and in the slaughter house. In this investigation we included the mass at the end of fattening. After 24 hours of chilling, a 7^{th} to 9^{th} thoracic rib cut was taken from the right carcass side.

Thoracic rib cuts were anatomically dissected and the share of each tissue component was determined (RAKO, 1960). Part of MLD (approximately 100 grams) was taken for chemical analysis. Samples were ground several times. Water was evaporated at 100 °C until constant weight. The nitrogen content was determined by the standard Kjeldahl procedure and expressed as protein content (nitrogen content multiplied by 6.25). Fat percentage was determined by the Soxhlet method using petrol ether extraction. Ash was determined by burning at 610 °C (KRIŽANOVIĆ, 1990).

SAS 8.0 and Statistica 7.1 software were used for all data analysis. Analysis of variance was performed for year, month and season of fattening end. Influences of various factors on variables were tested by analysis of variance, and post-hoc analysis was used for testing differences between different seasons. Relations among variables were tested by means of linear correlation. Regression analysis was applied for significant correlations. The influence of the sire on variables was tested by analysis of variance and covariance components (procedure MIXED, REML method in SAS). We calculated genetic and phenotypic variances and heritability using the following formulas:

$$\sigma^2_{phenotypic} = \sigma^2_{sire} + \sigma^2_{residual}$$

$$\sigma^2_{sire} = \text{half sibs covariance} = 0.25\ \sigma^2_{genotypic}$$

$$h^2 = 4\ (\sigma^2_{sire})\ /\ \sigma^2_{sire} + \sigma^2_{residual} = \sigma^2_{genotypic}\ /\ \sigma^2_{phenotypic}$$

Under genetic variance we considered its additive component.

Heritability was calculated with the fixed effects of year, season and month at the end of fattening and final body mass. We used the following model:

$$Y_{ijkmo} = \mu + o_i + G_j + S_l + M_k + Z_m + e_{ijklm}$$

Abbreviations stand for: Y = trait, μ = mean of the model, o_i = sire, G_j = year,M_k = month, S_l = season at the end of fattening, Z_m = final mass and e_{ijklm} = residual

The influence of the month was calculated as the month of the end of fattening, in a range from January to December.

Four seasons were taken into account as the end of fattening:

1. winter - from January to March (n = 163)
2. spring - from April to June (n = 119)
3. summer - from July to September (n = 168)
4. autumn - from October to December (n = 248).

Results

In Table 1 descriptive statistics are shown for final body mass and MLD mass according to season.The lowest final body and MLD mass were observed in summer.

Table 1. Season influence on final body mass and MLD mass ($X \pm \pm s_x$)

Season	N	Final mass - kg	MLD - g
Winter	163	$571.2^{a} \pm 4.43$	$1058.6^{a} \pm 14.19$
Spring	119	$569.7^{a} \pm 5.16$	$1024.4^{ab} \pm 15.58$
Summer	168	$559.6^{a} \pm 4.01$	$969.4^{b} \pm 14.94$
Autumn	248	$591.3^{b} \pm 3.66$	$1013.7^{ab} \pm 12.59$
All animals	698	575.3 ± 2.16	1015.4 ± 7.22

[a,b] values with different letter are significantly different (P<0.05)

Descriptive statistics of MLD chemical composition by season are shown in Table 2. We established lowest MLD dry matter and protein and on the other hand highest water, fat and ash content during summer.

Table 2. Season influence on MLD chemical composition ($X \pm s_x$)

Season	N	Dry matter %	Water %	Protein %	Fat %	Ash %
Winter	163	$25.01^{a} \pm 0.08$	$74.99^{a} \pm 0.08$	$20.43^{a} \pm 0.10$	$3.50^{a} \pm 0.12$	$1.07^{a} \pm 0.003$
Spring	119	$24.79^{ab} \pm 0.10$	$75.21^{ab} \pm 0.10$	$20.65^{ab} \pm 0.10$	$3.04^{ab} \pm 0.13$	$1.10^{b} \pm 0.003$
Summer	168	$24.60^{b} \pm 0.08$	$75.40^{b} \pm 0.08$	$20.39^{a} \pm 0.12$	$3.10^{ab} \pm 0.12$	$1.11^{b} \pm 0.004$
Autumn	248	$25.00^{a} \pm 0.07$	$75.00^{a} \pm 0.07$	$20.92^{b} \pm 0.09$	$2.98^{b} \pm 0.11$	$1.10^{b} \pm 0.002$
All animals	698	24.87 ± 0.04	75.13 ± 0.04	20.63 ± 0.05	3.14 ± 0.06	1.10 ± 0.002

[a,b] values with different letter are significantly different (P<0.05)

We calculated linear phenotypic correlations (Table 3). All correlations were significant except between ash and protein. Heritability estimates were moderate to high (on diagonal in Table 3).

Table 3. Linear phenotypic correlations among bulls' final mass and MLD chemical components and heritability values (on diagonal) for investigated traits

	Final mass kg	Dry matter %	Water %	Protein %	Fat %	Ash %
Final mass kg	0.73	0.29**	-0.29**	0.17**	0.05	-0.08*
Dry matter %	0.29**	0.60	-1.00**	0.20**	0.50**	-0.20**
Water %	-0.29**	-1.00**	0.60	-0.20**	-0.50**	0.20**
Protein %	0.17**	0.20**	-0.20**	0.40	-0.75**	-0.05
Fat %	0.05	0.50**	-0.50**	-0.75**	0.30	-0.10**
Ash %	-0.08*	-0.20**	0.20**	-0.05	-0.10**	0.36

*statistically significant at level $P<0.05$; ** statistically significant at level $P<0.01$

For high, statistically significant correlations we calculated regression formulas.

Simple linear regression between fat and dry matter, water and protein share in MLD with corresponding correlation coefficient (r), coefficient of determination (r^2) and probability level (P):

Dry matter (%) = 23.767 + 0.35434 * Fat (%)

$r = 0.533$; $r^2 = 0.2841$; $P<0.0001$

Water (%) = 76.233 - 0.3543 * Fat (%)

$r = -0.533$; $r^2 = 0.2841$; $P<0.0001$

Protein (%) = 22.661 - 0.6426 * Fat (%)

$r = -0.750$; $r^2 = 0.5629$; $P<0.0001$

Simple linear regression between the bulls' final mass and dry matter as well as water share in MLD with corresponding correlation coefficient (r), coefficient of determination (r^2) and probability level (P):

Dry matter (%) = 21.803 + 0.0053 * Final mass (kg)

$r = 0.286$; $r^2 = 0.0818$; $P<0.0001$

Water (%) = 78.197 - 0.0053 * Final mass (kg)

$r = -0.286$; $r^2 = 0.0818$; $P<0.0001$

Discussion

KARADJOLE (1978) and BOŽIĆ (2001) stated that various factors such as year, month and season affected the fattening capacity and chemical composition of Simmental bulls. These influences (year, season and month) were significant for most of the investigated parameters in our study (P<0.01). These factors influenced the investigated traits but the difference was also due to different microclimate, individual animal response and several other reasons.

Young bulls had higher average final mass (Table 1) compared to the mass recorded in other similar experiments (KARADJOLE, 1978; KRIŽANOVIĆ, 1990; BOŽIĆ, 2001). In those experiments the final mass ranged from 436.6 to 533.7 kg. The increase of final mass shows improvement by means of selection towards the higher final mass proclaimed by the National cattle breeding plan. The goal of the National cattle breeding plan is final mass between 550 and 600 kg. The differences previously mentioned showed that improvement occurred in the investigated period from 1993 to 2005. The variability of the trait was low.

Average values of most MLD chemical components were in accordance with the other authors, except for protein and fat (KARADJOLE, 1978; MIKULEC et al., 1978; KRIŽANOVIĆ, 1990; BOŽIĆ, 2001). In those trials, values for dry matter, water, protein, fat and ash were within the following ranges: for dry matter 24.37 to 25.37%, water 74.63 to 75.63%, protein 21.83 to 22.36%, fat 1.37 to 2.04% and ash 1.08 to 1.13%. While most of the components showed very low variability in all trials, variability of fat content was very high. In our experiment, protein content was lower and fat higher compared with previous investigations. This result could be explained by higher final mass (KARADJOLE et al., 1979; ROMPALA et al., 1985; CARSTENS et al., 1991; FIEMS et al., 2003; SAZILI et al., 2004; PATTERSON et al., 2004). Increase of final mass is connected with higher accretion of fat tissue, increased body fat percentage and decreased share of the other components at the same time (ROMPALA et al., 1985).

Seasonal influence could be due to intensity of metabolic activity (KARADJOLE, 1978). Several reasons might influence seasonal differences in final body and MLD mass. The lowest mass of these two parameters in summer time could be explained by the high external temperature and consequently reduced appetite. Furthermore, in summer the majority of heat (energy) is lost in evaporative body cooling (CUNNINGHAM, 1997).

The high and negative (-0.75) correlation between protein and fat implies that higher accretion of muscle fat is connected with decrease of protein content. Increased intramuscular fat may contribute to the juiciness and quality of meat. Heritability estimates were moderate to high and this should be considered when selecting AI bull's for meat production. These findings are in accordance with the results of other authors (BOŽIĆ, 2001; KRIŽANOVIĆ and KARADJOLE, 1993).

As shown in the results, MLD fat content is highly correlated with the other parameters in MLD. RAKO (1970) stated that intramuscular fat could be a very important selection criterion for establishing cattle meat quality.

Conclusions

Our results show that the investigated traits are correlated and that the year, month and season influence those traits. These facts should be considered when calculating phenotypic and genetic parameters for breeding animals, but also when choosing specific traits for sire selection. Selection success depends on the genetic variance of traits, as well as on the genetic correlations and heritability. When values of genetic variance and heritability are higher, and the genetic correlation among selected traits is stronger, progress in selection will be greater. Considerable variation of MLD fat content among sires of the same breed suggests that this could be a matter of further research in selection.

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SAŽETAK

Simentalska pasmina goveda je poznata kao pasmina dvojnih proizvodnih svojstava. To je najrasprostranjenija pasmina goveda u Republici Hrvatskoj te čini preko dvije trećine ukupne populacije goveda. Istraživali smo vrijednosti heritabiliteta za pokazatelje kemijskoga sastava (suhu tvar, vodu, bjelančevine, mast i pepeo) najdužega leđnoga mišića (m. longissimus dorsi, MLD) i njegove fenotipske osobine. Istraživanje je provedeno na 698 junadi, sinova bikova za umjetno osjemenjivanje u razdoblju od 13 godina. Prosječan kemijski sastav MLD bio je sljedeći: suha tvar 24,87 ± 0,04%, voda 75,13 ± 0,04%, bjelančevine 20,63 ± 0,05%, mast (eterski ekstrakt) 3,14 ± 0,06% i pepeo 1,10 ± 0,002%. Statističke analize obavljene su u SAS 8.0

(Statistical Analysis System) i Statistica 7.1 programskim paketima. Fenotipske korelacije između suhe tvari i vode, bjelančevina, masti i pepela bile su -1,00, 0,20, 0,50 te -0,20. Korelacije između vode i bjelančevina, masti te pepela bile su -0,20, -0,50 i 0,20. Koeficijent korelacije između bjelančevina i masti bio je -0,75; bjelančevina i pepela -0,05 te između masti i pepela -0,10. Sve su korelacije bile statistički značajne (P<0,01), izuzev između bjelančevina i pepela. Vrijednosti heritabiliteta za istraživana svojstva bile su: završna težina u tovu 0,73; suha tvar 0,60; voda 0,60; bjelančevine 0,40; mast 0,30 i pepeo 0,36. Utvrdili smo statistički značajan (P<0,001) utjecaj godine, sezone i mjeseca na kemijski sastav MLD. Vrijednosti fenotipskih korelacija i heritabiliteta treba uzeti u obzir pri selekciji bikova za umjetno osjemenjivanje za osobine tovnosti.

Ključne riječi: simentalsko govedo, meso, kemijski sastav, heritabilitet