MUSCLE FIBER CHARACTERISTICS OF FOUR MUSCLES FROM DIFFERENT CATTLE BREEDS AND THEIR RELATION TO MEAT INSTRUMENTAL TOUGHNESS

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Abstract – The objective of the present study was to compare the muscle fiber characteristics of four muscles (*longissimus lumborum* (LL), *semitendinosus* (ST), *biceps femoris* (BF) *and psoas major* (PM)) collected from 37 Aberdeen Angus (AA), Gascon (GS), Holstein (HO), and Fleckvieh (FL) young bulls reared under identical housing and feeding conditions. Furthermore, the relationships between histochemical characteristics and instrumental meat toughness were evaluated. Significant differences between muscles were found in muscle fiber cross-sectional area (CSA), fiber type proportions and in the relative area of the muscle occupied by each fiber type. The smallest CSA of all fiber types was detected in the PM muscle while the highest values were found for the type I in the ST muscle and for the types IIA and IIB in the BF muscle. The lowest fiber type proportions and the relative areas of the muscle for types I, IIA and IIB were observed in ST, LL and BF muscles, respectively. Significant breed differences were only found in the ST and BF muscle. Higher proportions of type I fibers were detected in AA and HO than in GS and FL bulls. On the contrary, GS and FL animals had higher relative areas occupied by IIB fibers than the other groups.

Key Words – Beef, fiber type, Warner-Bratzler shear force.

I. INTRODUCTION

In order to produce high quality meat it is necessary to evaluate variables related to animal production such as genetics as well as variables associated with processing of meat. Breed is an important factor that can influence the characteristics of the raw muscle tissue and hence of the finished product [1]. Because muscle fibers occupy 75 – 90% of the muscle volume, morphology of muscle fiber is a major determinant factor of muscle mass [2]. Special attention has been focused on muscle fiber types, because the variability in meat quality is often related to the metabolic and contractile properties of muscle fibers [3]. There are marked differences in the fiber type composition of different muscles, both within and between animals, which may influence meat quality and depend on factors such a body location, age, weight, and breed [4].

The aim of the present study was to evaluate the effects of muscle location and breed on muscle histochemical characteristics and their relationships to selected meat quality attributes.

II. MATERIALS AND METHODS

A total of 37 bulls of four contrasting breeds intended for beef and dairy production (Aberdeen Angus, AA, n = 10; Gascon, GS, n = 10; Holstein, HO, n = 8; Fleckvieh, FL, n = 9) were used. The bulls were finished under identical housing and feeding conditions and slaughtered at a similar age and live weight of approximately 17 months and 657 kg, respectively. Immediately after slaughter, muscle samples intended for fiber analyses were collected from right sides of carcasses. The samples of LL, ST, and BF were taken from the central part, while the samples of PM from the cranial part of the muscle. The samples were immediately frozen by immersion into isopentane, cooled by liquid nitrogen and were kept at -80°C until further analysis. For the determination of histological properties, serial transverse muscle sections (10 µm thick) were cut from entire blocks (1.0 × 1.0 × 2.0 cm) in a cryostat CM1850 (Leica Microsystems GmbH, Nussloch, Germany) at -20°C and mounted on glass slides. Fibers identified according to ATPase were classified as type I, type IIA and type IIB as described by Brooke and Kaiser [5]. The cross sectional areas (CSA) of each fiber type were determined in three randomly selected areas on serial sections with an image analysis software

program (NIS – Elements AR 3.2, Laboratory Imaging s.r.o., Prague, Czech Republic). On average, 200 fibers were analyzed in each serial section. Fiber type proportions and the relative area of muscle were determined. The fiber type proportion refers to the ratio of counted fiber numbers of each fiber type to the total counted fiber number and the relative area of muscle was the ratio of the total CSA of each fiber type to the total measured fiber area. Warner-Bratzler (WB) shear force was measured 24 h after slaughter. The muscle samples (2 × 1 × 1 cm) were sheared across fibers using an Instron Universal Texture Analyzer 3365 (Canton, MA, USA) with a V shaped blade running at a crosshead speed of 100 mm/min. The maximum mean force required to shear trough the sample was based on eight measurements for each sample.

Data were analyzed using a mixed linear model and parameters were estimated by the REML method of the MIXED procedure of the SAS statistical package [6]. The model included the fixed effects of breed and muscle and their interaction and the random effect of animal. Least squares means were calculated and multiple comparisons were made using Tukey's procedure. Pearson correlation coefficients (CORR procedure of SAS) were calculated to evaluate the association between muscle fiber characteristics and WB shear force.

III. RESULTS AND DISCUSSION

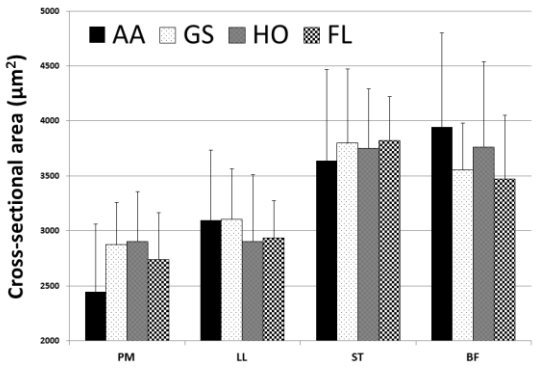

Figure 1: Fiber cross-sectional area in four muscles categorized by breeds (regardless of the fiber type)

The significance of main effects is shown in Table 1. The results revealed that the differences between muscles were markedly higher than the differences between breeds. The smallest CSA was observed in PM whereas the largest in ST and BF (Figure 1; Table 2). The lowest fiber type proportions and relative area of muscle for types I, IIA and IIB were observed in ST, LL and BF muscles, respectively. Similarly, Chriki *et al.* [7] found the average CSA of fibers greater in ST than in LL muscle.

Table 1 Significance of main effects on histochemical characteristics

	Muscle	Breed	M×B
Fiber cross-sectional area (µm²)			
I	***	NS	NS
IIA	***	NS	**
IIB	***	NS	NS
Fiber type proportions (%)			
I	***	**	NS
IIA	***	NS	NS
IIB	***	*	NS
Relative area of muscle (%)			
I	***	*	NS
IIA	***	NS	NS
IIB	***	*	*

NS - not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 2 Fiber composition of different muscles

	Type I	Type IIA	Type IIB
Fiber cross-sectional area (µm²)			
LL	2462 ^{A}	2867 ^{A}	3285 ^{A}
ST	2851 ^{B}	3216 ^{B}	4339 ^{B}
BF	2670 ^{AB}	3403 ^{B}	4431 ^{B}
PM	2176 ^{C}	2198 ^{C}	3215 ^{A}
Fiber type proportions (%)			
LL	28.2 ^{A}	12.6 ^{A}	59.2 ^{A}
ST	21.4 ^{B}	27.6 ^{B}	51.0 ^{B}
BF	27.8 ^{A}	26.1 ^{B}	46.1 ^{C}
PM	27.0 ^{A}	18.0 ^{C}	64.4 ^{A}
Relative area of muscle (%)			
LL	23.0 ^{A}	11.9 ^{A}	65.1 ^{A}
ST	16.7 ^{B}	23.6 ^{B}	59.7 ^{B}
BF	20.7 ^{A}	23.9 ^{B}	55.4 ^{C}
PM	21.5 ^{A}	14.1 ^{A}	64.4 ^{A}

$^{A, B, C}$ - Means in a column with different letters differ at $p<0.05$.

The breed differences in different muscles are shown in Tables 3, 4, 5 and 6, respectively. Significant breed differences were, however, found only in ST and BF muscles. In

ST, higher proportions of type I fibers were detected in AA and HO compared to the other breeds. On the contrary, GS and FL exhibited significantly higher relative area of muscle of type IIB fibers in ST and BF muscles.

Table 3 Fiber composition of *longissimus lumborum* (LL)

	Type I	Type IIA	Type IIB
Fibre cross-sectional area (μm²)			
AA	2650	3293	3294
GS	2602	2929	3352
HO	2301	2578	3204
FL	2338	2578	3272
Fibre type proportions (%)			
AA	28.8	12.7	58.5
GS	26.7	12.4	60.9
HO	28.6	9.0	62.4
FL	29.0	15.8	55.2
Relative area of muscle (%)			
AA	23.4	13.2	63.4
GS	22.6	11.3	66.1
HO	22.3	8.0	69.7
FL	23.7	14.6	61.7

In a study [1] that compared meat quality of fifteen European breeds, samples of AA and HO bulls were identified as those with the highest intramuscular fat content. In contrast, bulls of GS and FL are characterized with low intramuscular fat contents [8;9].

Table 4 Fiber composition of *semitendinosus* (ST)

	Type I	Type IIA	Type IIB
Fibre cross-sectional area (μm²)			
AA	2841	3434	4041
GS	2806	3048	4521
HO	2893	3521	4294
FL	2876	2890	4508
Fibre type proportions (%)			
AA	26.7 ^{A}	25.5	47.8
GS	18.4 ^{BC}	27.3	54.3
HO	23.5 ^{AC}	28.4	48.1
FL	17.1 ^{B}	29.3	53.6
Relative area of muscle (%)			
AA	21.7 ^{A}	24.0	54.3 ^{A}
GS	13.8 ^{BC}	21.4	64.8 ^{B}
HO	18.3 ^{AC}	26.5	55.2 ^{A}
FL	13.1 ^{B}	22.9	64.1 ^{B}

$^{A, B, C}$ - Means in a column with different letters differ at $p<0.05$.

Our results obtained for ST and BF muscles are in agreement with [4] who reported that lipids are mainly stored in type I fibers.

Table 5 Fiber composition of *biceps femoris* (BF)

	Type I	Type IIA	Type IIB
Fibre cross-sectional area (μm²)			
AA	2890	4066 ^{A}	4702
GS	2453	3037 ^{B}	4373
HO	2906	3711	4212
FL	2484	2883 ^{B}	4412
Fibre type proportions (%)			
AA	32.6	25.3	42.1
GS	24.5	26.5	49.0
HO	28.9	24.6	46.6
FL	25.6	27.9	46.4
Relative area of muscle (%)			
AA	24.3	25.5	50.2 ^{A}
GS	17.2	22.6	60.2 ^{B}
HO	23.7	24.5	51.8 ^{A}
FL	18.3	23.2	58.5 ^{B}

$^{A, B, C}$ - Means in a column with different letters differ at $p<0.05$.

Table 6 Fiber composition of *psoas major* (PM)

	Type I	Type IIA	Type IIB
Fibre cross-sectional area (μm²)			
AA	2022	1926	2822
GS	2191	2115	3434
HO	2234	2496	3419
FL	2272	2329	3215
Fibre type proportions (%)			
AA	27.7	18.9	53.4
GS	23.6	19.2	57.2
HO	27.2	18.1	54.7
FL	29.9	15.5	54.6
Relative area of muscle (%)			
AA	23.2	14.5	62.3
GS	17.9	14.3	67.8
HO	21.0	15.1	64.0
FL	24.3	12.5	63.1

Figure 2 shows WB shear force values measured in raw muscle samples. Whereas no significant differences were found between breeds, marked differences were observed between muscles. The relationships between muscle fiber characteristics and WB shear force are presented in Table 7. Although significant

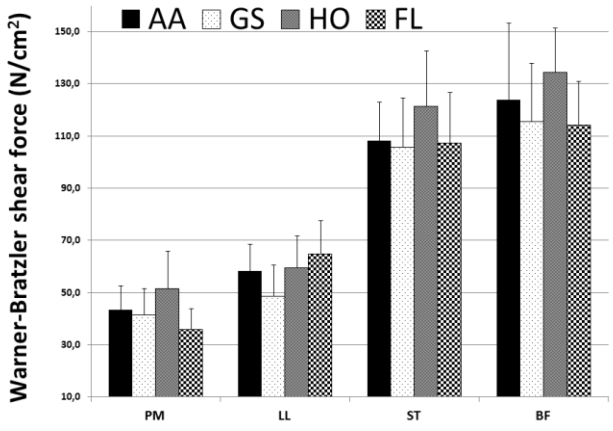

Figure 2: Raw meat instrumental toughness in four muscles categorized by breeds.

correlations between CSA and WB shear force were found for all fiber types, the closest relationship was detected for IIB. The relationships between WB shear force and proportions and the relative area of type I and IIA were in agreement with the results observed in Hanwoo steers [10]. However, the relationship between WB shear force and type IIB characteristics was not confirmed.

Table 7 Muscle fibre composition in *biceps femoris*

	Type I	Type IIA	Type IIB
Fibre cross-sectional area	0.25 **	0.35 ***	0.41 ***
Fibre type proportions	-0.12 NS	0.61 ***	-0.51 ***
Relative area of muscle	-0.14 NS	0.65 ***	-0.44 ***

NS - not significant, ***p<0.01, ****p<0.001*

IV. CONCLUSION

Clear differences in fiber CSA, fiber type proportions and the relative area of muscle were observed between muscles. Breed differences were only found in ST and BF muscles. AA and HO bulls had higher proportions of fiber type I, while higher proportions of IIB were detected in GS and FL breeds. In addition, significant correlations were observed between fiber characteristics and WB shear force measured in raw samples.

ACKNOWLEDGEMENTS

The study was supported by the Ministry of Agriculture of Czech Republic (project MZERO0714).

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