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RESEARCH ARTICLE

Quality Traits of Meat from Young Limousin, Charolais and Hereford Bulls

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ABSTRACT

The objective of this study was to determine the effects of beef cattle breed and muscle type on the proximate chemical composition and quality traits of meat, including processing suitability. The experimental materials comprised samples of *musculus longissimus dorsi* (LD muscle) and *musculus semitendinosus* (ST muscle) collected from the carcasses of young Limousin, Charolais and Hereford bulls. The chemical composition, texture, hydration and color parameters of LD and ST muscles were determined. Meat from Limousin and Charolais bulls, characterized by higher body mass at slaughter contained more protein than meat from Hereford bulls. Meat from Hereford bulls had a higher fat content, compared with the other two breeds. Texture parameters, including hardness, gumminess and chewiness, varied depending on muscle type and cattle breed. An analysis of the maximum shear force values showed that the mechanical properties of beef also varied depending on cattle breed and muscle type.

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INTRODUCTION

Beef cattle breeds provide high-quality beef characterized by a high nutritional value and an excellent taste (Beriain *et al.*, 2009). Meat quality is considerably affected by postmortem processes taking place in muscle tissue, including changes in meat pH (Herring *et al.*, 2010). Postmortem aging is determined by proper pH levels. Beef quality and muscle microstructure are also influenced by the age and feeding regime of animals (Ahnström *et al.*, 2009; Iwanowska and Pospiech, 2010). The rate of postmortem aging is faster in the muscle tissue of younger cattle. Muscle fiber surface area and sarcomere length also vary depending on the age of animals and muscle type (Wan *et al.*, 2011; Ahnström *et al.*, 2012).

Color, tenderness, texture, marbling and water-holding capacity are among the most important beef quality criteria a consumer considers while making a purchase decision (Wiegand *et al.*, 2006). The nutritional value of beef is due to high levels of intramuscular fat and protein (Muchenje *et al.*, 2012). At the time of slaughter, adequate glycogen reserves and ATP levels are required to achieve the optimal eating quality of beef (Kim *et al.*, 2000). The meat acidification process and tenderness are determined by the type of metabolism in muscle fibers, their size and number in the bundle. As demonstrated by Muchenje *et al.* (2009), glycogen levels are affected by muscle type and the live weight of bulls at slaughter. The most important characteristics of the microstructure of skeletal muscle tissue are the size of muscle fibers and the percentage of specific fiber types.

The objective of this study was to determine the effects of beef cattle breed and muscle type on the proximate chemical composition and quality traits of meat, including processing suitability.

MATERIALS AND METHODS

The experimental materials included samples of *m. longissimus dorsi* (LD muscle) and *m. semitendinosus* (ST muscle) collected from the carcasses of young (18 months age) Limousin race (11), Charolais (15) and Hereford (17) bulls (uncastrated). All animals were fed maize silage and mixed concentrate feed. The mean body mass of bulls at slaughter was 573, 600 and 502 kg for Limousin, Charolais and Hereford, respectively. After 24-hour chilling at 4^{o}C, samples of LD muscle (from the region of the 13th thoracic vertebra) and ST muscle were collected from the right half-carcasses for laboratory analyses, performed 48 hours post-mortem. The pH of both muscles was measured using a PHM80 portable pH-meter equipped with a GK2401C electrode (Radiometer Analytical). Meat color was measured by the reflectance method, using a Spectro-color (CL-4606) apparatus (Hoch Lange GmBH) with an aperture diameter of 8 mm, a light source D65, a standard colorimetric observer with visual field of 10º and SPECTRAL – QC. Trichromatic coordinates were determined according to the CIE color System: L* (lightness), a* (redness), b* (yellowness) and C* (chroma). The maximum shear force was measured using a Warner-Bratzler head attached to an Instron universal testing machine (Instron Corporation, USA, model 4301), on 10 x 10 mm samples cut along muscle fibers from LD and ST muscles that had been cooked at $80^{o}C$ for one hour. The texture profile analysis (TPA) involved a double compression test. 10 x 10 x 10 mm samples were compressed twice (perpendicular to the direction of muscle fibers) to 50% of the original height. The following texture parameters were determined: hardness, springiness, gumminess and chewiness. Cooking loss (%) was determined together with the texture profile analysis. The remaining parameters were measured on muscle samples ground three times in a meat grinder, mesh size 3 mm. The content of dry matter, fat (Soxhlet method PN -71/A-88021, 1971), total protein (Kjeldahl method, PN-75/A-04018, 1975 - Kieltec 1026 Distilling Unit, Teactor) and ash were determined. The total collagen content of muscles was determined using a conversion factor of 7.46 (Jankowska *et al.*, 2000). The liquid area (cm^2) was measured with a Robotron planimeter (Reiss Precision, Germany).

The results were processed statistically by an analysis of variance (ANOVA). Arithmetic means and standard errors (SE) were calculated by Statistica ver. 9.1. The significance of differences between means was determined by Duncan's test at a significance level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Meat quality was affected by a wide range of factors. The nutritional value of beef is determined by its chemical composition, mostly protein and fat content. The eating quality and consumer perception of beef are affected primarily by color and tenderness, whereas its processing suitability is influenced by the status of muscle tissue hydration. The average dry matter content of meat samples from bulls of three breeds (Table 1) was slightly above 23%, with an insignificantly lower water content of LD muscle. Significant differences were noted between the studied cattle breeds with respect to the protein content of meat, which ranged from 19.91% in Hereford to 21.10% in Charolais. Similar chemical composition of beef from young Charolais bulls has been reported by Renand *et al*. (2001). The higher protein content of muscles in Charolais cattle could be due to their highest body mass at slaughter, which supported the findings of Hoch *et al*. (2005) who demonstrated that beef from cattle characterized by higher live weight and carcass weight usually contains more protein.

The meat of Hereford bulls had the highest fat content (in both muscles), and the meat of Charolais bulls had the lowest fat concentrations. The noted differences were statistically significant. The amount and distribution of intramuscular fat affect the nutritional properties, texture and juiciness of beef, thus contributing to its desirable tenderness. Chambaz *et al.* (2002) found that the fat content of beef is influenced by cattle genotype.

The nutritional value of meat is determined not only by total protein levels, but also by the content of connective tissue proteins whose presence improves beef tenderness and texture (Bartoň *et al.*, 2010). In the present study, differences in collagen content were due to muscle type, not the breed. The ST muscle had significantly higher collagen content than the LD muscle (Table 1). Major factors responsible for collagen concentration of meat include genotype of the cattle (Christensen *et al.*, 2011), feeding regime (Vestergaard *et al.*, 2000b) and age at slaughter (Renand *et al.*, 2001).

Table 1: Chemical composition of *musculus longissimus dorsi* (LD) and *musculus semitendinosus* (ST)

Parameter	Muscle	Breed		
		Limousin	Charolais	Hereford
Dry matter	LD	23.67 ± 0.05^{ax}	23.33 ± 0.09^{ax}	23.59 ± 0.26^{ax}
[%]	ST	23.23 ± 0.08^{ax}	23.05 ± 0.28^{ax}	23.04 ± 0.20^{ax}
Protein [%]	LD	21.08 ± 0.13^{ax}	21.10 ± 0.15^{ax}	19.91 ± 0.13^{bx}
	ST	20.32 ± 0.12^{ay}	20.70 ± 0.13^{ay}	20.11 ± 0.13^{ax}
Total collagen	LD	422 ± 20.79^{ax}	419 ± 14.52^{ax}	417 ± 27.06^{bx}
[mg/100g]	ST	599 ± 35.41^{ay}	622 ± 41.37^{by}	576 ± 29.44^{cy}
Fat [%]	LD	1.54 ± 0.12^{ax}	0.71 ± 0.16^{bx}	2.28 ± 0.32^{cx}
	ST	1.10 ± 0.21^{ay}	0.81 ± 0.13^{bx}	1.38 ± 0.23^{cy}
Ash [%]	LD	1.05 ± 0.01^{ax}	1.08 ± 0.01^{bx}	1.01 ± 0.01^{cx}
	ST	1.09 ± 0.01^{ay}	1.11 ± 0.01^{ay}	1.03 ± 0.01^{bx}

a,b - values (mean±SE) in a row regarding breeds and x,y - values in columns regarding LD and ST muscles within a parameter followed by different superscript letters are significantly ($P<0.05$) different.

The texture parameters of beef samples have been presented in Table 2. An instrumental analysis of meat texture usually involves the use of the Warner-Bratzler shear force test (Caine *et al.*, 2003; Hwang *et al.*, 2004). Tenderness is one of the most difficult to measure sensory attributes of meat. The measurement of the maximum shear force showed that the ST muscle was tenderer than the LD muscle, irrespective of cattle breed. The average shear force values for the LD muscles ranged from 99.71 N (Charolais) to 104.80 N (Limousin), while the values determined for the ST muscle were significantly lower. Meat from Charolais bulls differed significantly from the other two breeds with respect to the maximum shear force. In a study by Dasiewicz and Słowiński (2007), cattle breed had no significant effect on shear force and compressive force values. The texture profile analysis (TPA) applied in the study enabled to measure several beef texture parameters based on deformation during compression. Hardness, i.e. the force required attaining 50% deformation, decreased significantly depending on muscle type and cattle breed. The maximum compressive force (after 48 h) reached approximately 55 N for ST muscle samples from Limousin bulls, and 41 N for ST muscle samples from Charolais and Hereford bulls. A similar trend was observed with regard to springiness, defined as the rate at which a specimen returns from a deformed state to its original state, which ranged from 0.35 to 0.60 mm. Cattle breed and muscle type influenced also beef gumminess and chewiness. The texture parameters quantified from a double compression test as well as the mechanical properties of beef were affected by cattle breed and muscle type. Our results are consistent with the findings of King *et al*. (2010) and Juszczuk-Kubiak *et al*. (2009) who reported significant differences in the eating quality and sensory attributes of meat from different sire breeds. The ST muscle was characterized by higher springiness and chewiness values.

Table 2: Texture parameters of *musculus longissimus dorsi* (LD) and *musculus semitendinosus* (ST)

Parameter	Muscle	Breed		
		Limousin	Charolais	Hereford
Maximum shear	LD	104.80 ± 5.21^{ax}	99.71 ± 5.81^{bx}	104.52 ± 6.38^{ax}
force[N]	ST	96.14 ± 4.99^{by}	73.71 ± 5.85^{cy}	87.15 ± 5.62^{dy}
Hardness [N]	LD	49.61 ± 2.77^{ax}	34.72 ± 3.45^{bx}	41.67 ± 2.62^{cx}
	ST	55.16 ± 3.08^{dy}	41.26 ± 4.38^{cy}	41.13 ± 2.54^{cx}
Springiness	LD	0.59 ± 0.01^{ax}	0.35 ± 0.02^{bx}	0.49 ± 0.02^{cx}
[mm]	ST	0.60 ± 0.02^{ax}	0.38 ± 0.02^{by}	0.50 ± 0.02^{cx}
Gumminess [N]	LD	27.24 ± 1.76^{ax}	13.43 ± 1.23^{bx}	16.65 ± 1.64^{cx}
	ST	29.66 ± 1.55^{ay}	16.68 ± 1.23^{cy}	19.99 ± 1.93^{cy}
Chewiness	LD	16.02 ± 2.90^{ax}	33.97 ± 3.47^{bx}	26.94 ± 4.32^{cx}
[J 10^{-3}]	ST	18.39 ± 4.05^{ay}	48.42 ± 3.58^{by}	33.99 ± 5.64^{cy}

a,b - values (mean±SE) in a row regarding breeds and x,y - values in columns regarding LD and ST muscles within a parameter followed by different superscript letters are significantly (P<0.05) different.

The value of pH_{48} is a key quality attribute of meat, as it affects the beef aging process (Ahnström *et al.*, 2009). According to Juszczuk-Kubiak (2009), normal-quality meat has pH_{48} of 5.5 – 5.7. Such pH levels support beef aging, and the meat becomes light in color, tender and tasty. Low pH values contribute to myoglobin oxygenation which leads to the formation of a thick layer of bright-red oxymyoglobin on meat surface (King *et al.*, 2010). The pH of muscles has an influence on the processing suitability of beef, including water-binding capacity, tenderness, color and shelf-life (Swan and Boles, 2002; Purchas *et al.*, 1999; Sakowski *et al.*, 2001).

In our experiment, average pH levels determined 48 hours post-mortem (Table 3) ranged from 5.50 to 5.87. Meat from Charolais bulls had the lowest pH (5.52 in the LD muscle and 5.50 in the ST muscle), and the differences between this breed and the other two breeds were statistically significant.

Table 3: Hydration of *musculus longissimus dorsi* (LD) and *musculus semitendinosus* (ST)

Parameter	Muscle	Breed		
		Limousin	Charolais	Hereford
pH_{48}	LD	5.82 ± 0.01^{ax}	5.52 ± 0.01^{bx}	5.87 ± 0.01^{ax}
	ST	5.74 ± 0.02^{ax}	5.50 ± 0.03^{bx}	5.75 ± 0.01^{ax}
Cooking	LD	31.51 ± 0.38^{ax}	43.79 ± 0.82^{bx}	41.33 ± 0.52^{bx}
loss [%]	ST	35.69 ± 0.42^{ay}	45.72 ± 0.26^{by}	43.99 ± 0.56^{by}
Liquid	LD	3.79 ± 0.22^{ax}	10.21 ± 0.25^{bx}	7.55 ± 0.15^{cx}
area [cm^2]	ST	4.60 ± 0.25^{ay}	10.54 ± 0.29^{bx}	9.08 ± 0.18^{by}

a,b - values (mean±SE) in a row regarding breeds and x,y - values in columns regarding LD and ST muscles within a parameter followed by different superscript letters are significantly (P<0.05) different.

An increase in acidity decreases the diameter of microcapillary spaces, thus reducing the water-holding capacity of proteins. The hydration properties of meat change in response to various factors (Jukna, 2002). In this experiment, cooking loss was higher in meat from Charolais and Hereford bulls than that of Limousin (Table 3). Within breeds, the LD and ST muscles differed significantly ($p \geq 0.05$) with respect to pH_{48} levels, cooking loss (%) and liquid area (cm^2). The values of cooking loss and liquid area were significantly lower in the LD muscle (P<0.05).

Consumers often evaluate beef based on color. Beef color is affected by cattle breed, pH, water content, intramuscular fat and connective tissue (Purchas *et al.*, 1999; Hulsegge *et al.*, 2001). Table 4 shows the color parameters of the studied beef muscles. Significant differences in color were noted between cattle breeds and muscle types. The muscles of Charolais bulls were lightest in color. Regardless of breed, the ST muscles had a lighter color than the LD muscle, and the color of the former had a lower contribution of redness. The muscles differed also as regard color saturation. Muscle color is influenced by the age at slaughter and feeding regime. Hulsegge *et al.* (2001) reported that veal carcasses had a very light color (47.34), with a low contribution of redness (10.03) and yellowness (3.00). In a study by Purchas *et al. (*1999) the color lightness, redness and yellowness in older animals reached 30.7, 16.1 and 6.3, respectively.

Table 4: Color parameters of *musculus longissimus dorsi* (LD) and *musculus semitendinosus* (ST)

Parameter	Muscle	Breed		
		Limousin	Charolais	Hereford
Lightness	LD	12.84 ± 0.99^{ax}	26.60 ± 1.00^{bx}	17.64 ± 0.92^{cx}
	ST	19.80 ± 1.13^{cy}	32.56 ± 1.26^{dy}	30.71 ± 0.72^{dy}
Redness	LD	20.48 ± 0.88^{ax}	14.78 ± 1.16^{bx}	18.67 ± 0.82^{cx}
	ST	17.87 ± 0.69^{cy}	9.56 ± 0.98^{dy}	14.93 ± 0.75^{by}
Yellowness	LD	15.06 ± 0.35^{ax}	24.73 ± 0.77^{bx}	19.78 ± 0.57^{cx}
	ST	20.36 ± 0.40^{dy}	24.58 ± 0.44^{bx}	23.94 ± 0.37^{by}
Chroma	LD	25.32 ± 0.89^{ax}	28.88 ± 1.10^{bx}	27.61 ± 0.43^{bx}
	ST	27.99 ± 1.04^{by}	26.44 ± 0.56^{ay}	26.41 ± 0.53^{ax}

a,b - values (mean±SE) in a row regarding breeds and x,y - values in columns regarding LD and ST muscles within a parameter followed by different superscript letters are significantly (P<0.05) different.

Wajda and Daszkiewicz (2010) compared the quality of meat from young crossbred bulls produced by mating Polish Holstein-Friesian cows to Limousin and to Charolais bulls. The cited authors found that that the incidence of carcass damage was lower when bulls were held in individual boxes in lairage prior to slaughter. Meat from bulls placed in single boxes, compared with meat from bulls kept loose in group boxes, was characterized by a higher percentage content of dry matter, a lower pH_{48} value and a lighter color. Better tenderness of meat from bulls held in group boxes was due to higher pH values. Beef from PHF x LIM bulls, compared with meat from PHF x CH crossbreeds, had a higher percentage content of ash and a lower pH_{48} value.

Conclusions: Meat of Limousin and Charolais bulls, characterized by higher body mass at slaughter, contained more protein than the meat of Hereford bulls. Meat of Hereford bulls had a higher fat content, compared with the other two breeds. Texture parameters, including hardness, gumminess and chewiness, varied depending on muscle type and cattle breed. An analysis of the maximum shear force values showed that the mechanical properties of beef also varied depending on cattle breed and muscle type.

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