

## CHANGES OF PHYSICOCHEMICAL PROPERTIES OF BULLOCKS AND HEIFERS MEAT DURING 14 DAYS OF AGEING UNDER VACUUM\*

Mariusz Florek, Anna Litwińczuk, Piotr Skąlecki, Małgorzata Ryszkowska-Siwko

Department of Animal Raw Material Estimation and Utilization, Agricultural University, Lublin

Key words: cattle, sex, vacuum-packed meat, cold storage, ageing, physicochemical properties

The objective of the work was to evaluate the effect of conditioning time (during 14 days of ageing under vacuum) and sex (heifers vs. bullocks) on physicochemical properties of two beef skeletal muscles. The research material was made by random samples of *m. longissimus dorsi* (lumbar region) – LL and *m. semitendinosus* – ST from carcass of bullocks (n=12) and heifers (n=12), at the age of 18 months of Polish Holstein-Friesian breed Black-and-White strain. The pH, specific electrical conductivity – EC (mS/cm), CIE L\*a\*b\* values, shear force and drip loss were measured. There was demonstrated a significant influence of sex on pH, colour (a\* and b\* values) and natural drip loss from the LL and ST muscle. Over the 14 day conditioning period, tenderness improved significantly along with steady growth of specific electrical conductivity of the evaluated muscles. The meat of heifers aged for 14 days under vacuum was characterised by lower pH, higher specific electrical conductivity, greater natural drip loss as well as more of red colour (higher a\*) and of yellow (higher b\*) as compared to the young bulls meat.

### INTRODUCTION

Beef from young cattle is appropriated mainly for the culinary meat. Muscle is composed of a heterogenous mixture of fibre types, and different types differ in their biochemical and physical properties. For example bovine *semitendinosus* contains significantly higher proportion of white and intermediate fibres than *biceps femoris*, which contains a higher proportion of red fibres [Hertzman *et al.*, 1993]. The red fibres have a higher concentration of myoglobin and are generally lower in glycogen and higher in lipid content than the white fibres. White muscles are high in glycolytic enzymes and they twitch faster in response to stimulation, contract and relax faster, and fatigue faster than red muscles, which are high in oxidative enzymes. White muscles have a faster rate of pH fall, enter rigor earlier and age faster than the red fibres.

In a retail environment, colour is a critical sensory characteristic of beef as it is experienced by consumers before tenderness or flavour and tends to be used as an indicator of perceived quality and freshness [Carpenter *et al.*, 2001]. Therefore colour is probably the single greatest appearance factor that determines whether meat will be purchased.

Colour can be adversely affected at all steps of the production chain, including animal breed, diet and age; pre-slaughter handling, stunning and bleeding; chilling variables; fabrication and aging times and temperature; packaging, distribution and marketing, including lighting and other display conditions [Kropf, 1993]. Measuring bovine muscle colour is also important due to a relationship between ultimate muscle pH and (or) muscle colour and meat tenderness [Purchas *et al.*, 1999; Watanabe *et al.*, 1995; Wulf *et al.*, 1997].

Breed is one of the main productive factors that influence the quality of meat. The effect of breed on meat colour can be explained by the precociousness of the animals [Rennerre, 1984]. Thus, dairy cattle have a more unstable colour than the beef cattle [Faustman & Cassens, 1990; Insausti *et al.*, 1999].

Removal of oxygen from the package prevents the growth of aerobic organisms responsible for rapid spoilage and allows storage of meats for several weeks [Lawrie, 1991]; however vacuum-packaged meats retain the purplish colour of deoxymyoglobin and lack of the fresh meat colour associated with oxymyoglobin [Faustman *et al.*, 1996]. Beef aged in vacuum packaging is darker in colour when removed from the package due to the lack of oxygen. Rennerre & Mazuel [1985] found that when beef pigment contained 20% metmyoglobin, sales decreased by 50%.

Temperature and post slaughter storage life influence substantially the *postmortem* changes rate and, in a consequence, beef meat tenderness development [Purchas *et al.*, 1999].

The objective of the work was to evaluate the effect of conditioning time and sex on physicochemical properties of two skeletal muscles.

### MATERIALS AND METHODS

The research material was made by random samples of *m. longissimus dorsi* (lumbar region) – LL and *m. semitendinosus* – ST from carcass of bullocks (n=12) and heifers (n=12), at the age of 18 months of Polish Holstein-Friesian breed Black-and-White strain. The animals came from south-eastern region of Poland. The average slaughter weight

Author's address of correspondence: Mariusz Florek, D. Sc., Department of Animal Raw Material Estimation and Utilization, Agricultural University, Akademicka 13, 20-950 Lublin, Poland; tel.: (48 81) 445 66 21; e-mail: mariusz.florek@ar.lublin.pl

of bullocks was 486 kg ( $\pm 34$  kg), and that of heifers 467 kg ( $\pm 27$  kg). Stunning and slaughter of cattle were performed in compliance to the regulations obligatory in the meat industry and veterinary inspection supervision. After the 24-h post slaughter chilling during the technological partition of the right half-carcass the LL and the whole ST were cut out. Then they were divided into 4 sections of the same length, weighed and vacuum packed in the PA/PE foil bags. The bags were cold stored at 2–4°C temperature for 2, 7 and 14 days prior to analysis.

The PQM I-KOMBI INTEK GmbH apparatus was employed to determine pH reaction and specific electrical conductivity – EC (mS/cm) directly into intact muscle tissue, taking the measurements 45 min, and 1 (24 h), 2 (48 h), 7 and 14 days following the slaughter.

The colour of fresh cut meat surface following 30 min blooming time (samples were stored in contact with air at 4°C) was measured immediately after the meat had been removed from the vacuum bag using Minolta CR-310 portable chromameter (illumination D65, geometry 0 projection angle and 50 mm measure area). The measurements were taken on days 1, 2, 7 and 14. Values were given in the colour space CIE [CIE, 1976], where L\* – metrical lightness; a\* – redness; b\* – yellowness. A result for a sample was computed as an arithmetic mean from three replications on the muscle surface.

The shear force (SF) was measured by means of tenderometer SZ type with a Warner-Bratzler shearing device registering the maximum force (kG) required to disrupt 1 cm<sup>2</sup> meat blocks perpendicular to the grains, at a crosshead speed of 150 mm/min. A higher reading indicated greater shear force and therefore tougher meat. The measurements were

taken 2, 7 and 14 days following the slaughter after thermal treatment of the samples (in thin-walled plastic bags) in the water bath at 75°C. After 1 h, the samples were cooled in tap water and stored at 4°C for 1 day. Blocks were cut parallel to the direction of the muscle fibres. From each meat sample a minimum of eight blocks were tested.

Drip loss (DL) was expressed as a percentage of the initial weight of meat sample (before packaging) to samples stored for 2, 7 and 14 days.

The obtained data were analysed statistically using the program STATISTICA ver. 6 [StatSoft, 2003] by means of a two-way analysis of variance in order to study the sex effect and the storage time effect and their interactions. Fisher LSD test was used for Post-hoc comparisons.

## RESULTS AND DISCUSSION

The *m. longissimus dorsi* (LD) and *m. semitendinosus* (ST) represent different types of muscle; therefore their culinary use is different as well. The LD, owing to its high commercial value and possible use at household and the catering business (usually as steaks), is the most often evaluated muscle. It is characterised with a low connective tissue level, but due to its elevated susceptibility to the *postmortem* shortening and anatomical location (near the carcass surface), its tenderness depends on the cooling rate as well as carcass weight and adiposis. So, it proves to be the least suitable muscle to represent the total (general) carcass tenderness. Whereas, the ST appears more resistant to the excessive shortening of sarcomeres, it shows higher connective tissue level so it fits better (as indicator muscle) for the general evaluation of carcass tenderness [Shorthose & Harris, 1990].

TABLE 1. Effect of sex and ageing time on physicochemical properties of beef muscles (mean $\pm$ SE).

Muscle	Trait	Sex (S)			Ageing time (A)						Interaction effect S x A <i>p</i>
		heifers	bullocks	<i>p</i>	45 min	24 h	48 h	7 d	14 d	<i>p</i>	
LL											
	pH	5.73 (0.08)	5.99 (0.08)	0.0000	6.68 (0.07)	5.70 (0.08)	5.59 (0.08)	5.64 (0.07)	5.66 (0.06)	0.0000	0.4078
	EC (mS/cm)	7.80 (0.83)	6.23 (0.65)	0.0104	3.04 (0.14)	3.94 (0.46)	6.42 (0.81)	8.74 (0.77)	12.93 (1.08)	0.0000	0.0388
	CIE										
	L	38.94 (0.40)	38.17 (0.49)	0.2500	–	38.34 (0.50)	38.37 (0.41)	38.54 (0.80)	38.96 (0.79)	0.9076	0.9065
	a*	20.24 (0.26)	18.72 (0.48)	0.0060	–	18.81 (0.38)	18.72 (0.46)	19.99 (0.75)	20.38 (0.57)	0.0698	0.7455
	b*	3.21 (0.20)	1.83 (0.30)	0.0003	–	2.02 (0.30)	2.25 (0.33)	2.57 (0.47)	3.24 (0.45)	0.0964	0.7975
	DL (%)	2.82 (0.32)	1.36 (0.41)	0.0077	–	–	1.54 (0.37)	1.86 (0.37)	2.87 (0.64)	0.1041	0.7833
	SF (kG)	5.64 (0.37)	4.78 (0.59)	0.1819	–	–	6.36 (0.66)	5.37 (0.52)	3.89 (0.46)	0.0113	0.4446
ST											
	pH	5.71 (0.08)	5.85 (0.08)	0.0002	6.65 (0.05)	5.63 (0.05)	5.45 (0.03)	5.57 (0.05)	5.60 (0.04)	0.0000	0.0452
	EC (mS/cm)	8.74 (0.78)	7.54 (0.88)	0.1786	3.09 (0.24)	7.29 (1.18)	7.66 (1.17)	9.00 (0.97)	13.66 (0.97)	0.0000	0.7204
	CIE										
	L	41.57 (0.35)	42.47 (0.44)	0.1362	–	41.96 (0.54)	41.81 (0.54)	41.81 (0.59)	42.51 (0.65)	0.8124	0.9690
	a*	21.72 (0.30)	20.23 (0.21)	0.0000	–	20.07 (0.31)	20.30 (0.21)	21.54 (0.42)	21.99 (0.46)	0.0000	0.1578
	b*	4.97 (0.25)	3.85 (0.27)	0.0010	–	3.66 (0.33)	3.87 (0.25)	4.86 (0.41)	5.25 (0.41)	0.0019	0.2799
	DL (%)	3.14 (0.35)	2.07 (0.38)	0.0289	–	–	2.26 (0.47)	2.01 (0.42)	3.53 (0.43)	0.0264	0.1142
	SF (kG)	2.96 (0.29)	2.89 (0.28)	0.8683	–	–	3.74 (0.34)	2.60 (0.31)	2.44 (0.28)	0.0129	0.8316

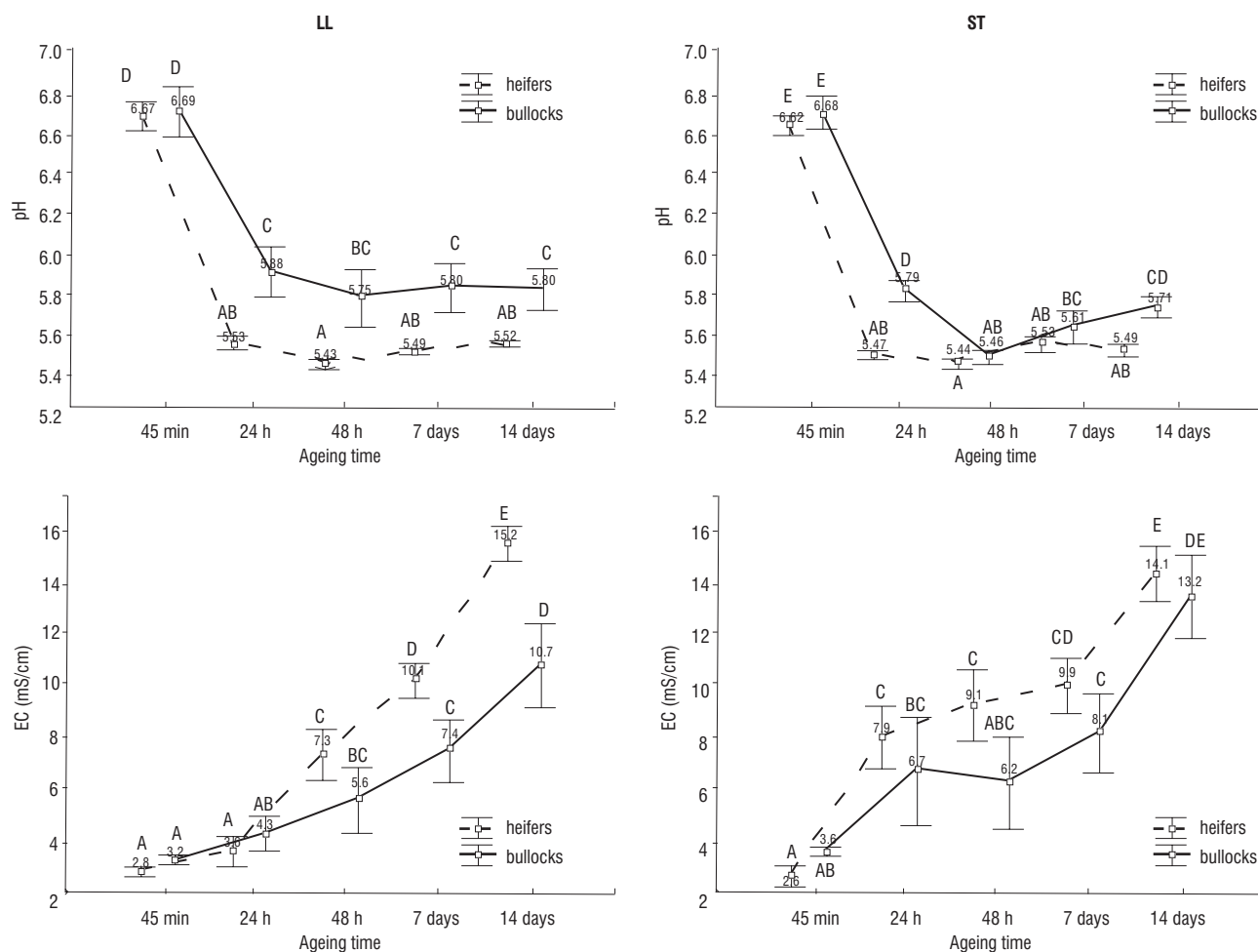


FIGURE 1. Changes of pH and electrical conductivity of beef muscles depending on sex and ageing time (mean  $\pm$  SE). A,B,C,D,E – for each muscle means bearing different superscript differ significantly at  $p < 0.01$ .

A basic parameter of meat quality assessment is pH value. Lawrie [1985] reported that the rate and extent of pH decrease were influenced by intrinsic factors such as species, breed, muscle and animal variability and by extrinsic factors such as environmental temperature and degree of stress.

A significantly higher ( $p < 0.01$ ) pH of the LL and ST muscle was recorded in young bulls compared to the heifers. Alike, ageing time exerted a significant impact on pH change in the studied muscles (Table 1). There was shown a fall of this value over the first 48 h followed by a slight and constant growth till the 14<sup>th</sup> day of conditioning time.

The initial pH decline is caused by lactic acid accumulation during glycolysis and proves the appropriate run of the meat acidification process. The later pH rise arises from the progressing alkalization caused by the release of basic products of protein breakdown throughout the post-slaughter endogenous changes (ageing).

In the LL muscle there were shown significant ( $p < 0.01$ ) differences in pH values between young bulls and heifers for the successive measurements over the conditioning period (except 45 min), whereas for the ST – the differences were observed after 24 h and 14 days (Figure 1).

The electrical conductivity is a direct measurement of muscle juice drip [Pliquett *et al.*, 1990]. It results from cellular membranes weakening in the muscle tissue after slaughter and holding of water by miofilaments that make the fluids translocate within the intra- and intercellular space.

Significantly lower specific electrical conductivity was manifested by the LL muscle of young bulls as compared to the heifers, lower values were also noted for the ST. The significant EC rise was detected during the conditioning period of the examined muscles (Table 1). Analysing the electrical conductivity changes in the LL muscle over the conditioning time subject to a sex, some significantly lower values of EC were found in the bulls on the 7<sup>th</sup> and 14<sup>th</sup> day. However, no differences were recorded in the ST conductivity in the bulls and heifers over the tempering time (Figure 1).

According to Byrne *et al.* [2000], who evaluated the quality of the heifers LD, electrical conductivity increased over the conditioning time from 2.3 mS/cm on the 1<sup>st</sup> day after slaughter, 5.4 on the 5<sup>th</sup> day and 8.6 on the 7<sup>th</sup> day up to 14.6 on the 14<sup>th</sup> day.

Although meat colour is a poor guide to eating quality, most consumers make purchase decisions based on display colour. Consumers discriminate against meat that is not red and bright [Hood & Riodan, 1973], considering it is old or of poor quality [Young *et al.*, 1999].

Evaluating the colour parameters CIE Lab of the LL and ST (Table 1), a significant impact ( $p < 0.01$ ) of sex was found on the  $a^*$  and  $b^*$  values. The higher values of these parameters were found in the heifers meat. The conditioning time induced growth of the  $L^*a^*b^*$  values of the LL muscle, but the differences were proved to be insignificant. Similar and significant ( $p < 0.01$ ) tendencies were reported for  $a^*$  and  $b^*$

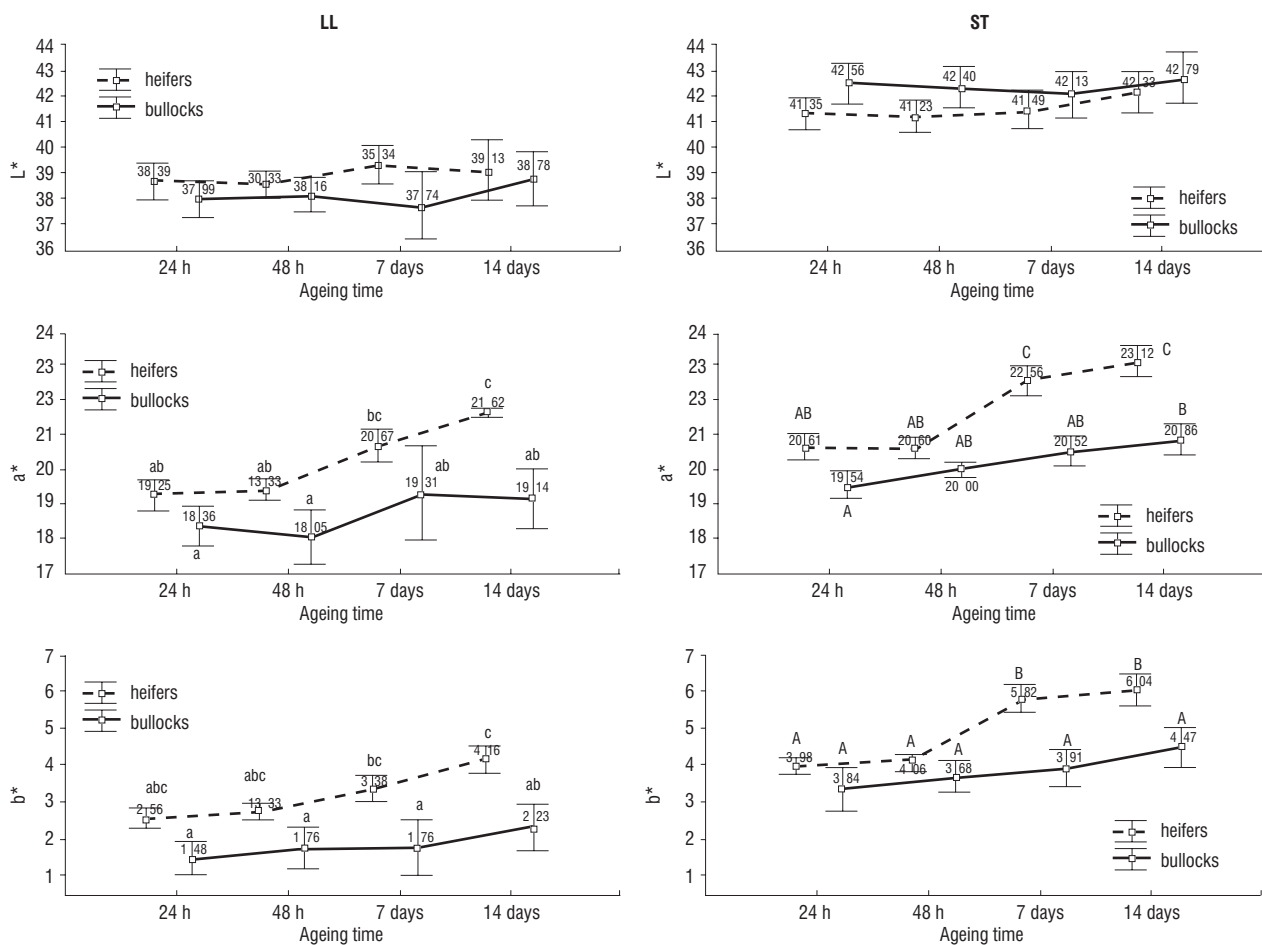


FIGURE 2. Changes of CIE  $L^*a^*b^*$  values of beef muscles depending on sex and ageing time (mean  $\pm$  SE). A, B, C – for each muscle means bearing different superscript differ significantly at  $p < 0.01$ . a, b, c – for each muscle means bearing different superscript differ significantly at  $p < 0.05$ .

of the ST muscle. However, there was not shown any significant influence of sex and ageing time on  $L^*$  value of the muscles studied. In the initial storage period (after 24 and 48 h), the  $a^*$  and  $b^*$  values in the examined muscles of young bulls and heifers were similar, whereas significantly lower values of these parameters were recorded in the bulls on the 7<sup>th</sup> d and 14<sup>th</sup> day of conditioning time (Figure 2).

Alike, Oliete *et al.* [2006] found that lengthening of the vacuum storage time of *m. longissimus thoracis* (1<sup>st</sup>, 7<sup>th</sup> and 14<sup>th</sup> day) resulted in a rise of the  $a^*$  and  $b^*$  parameters, *i.e.* meat became more red and yellow, with a more pink hue (higher  $H^{\circ}$ ), while the colour saturation was more intensive (higher  $C^*$ ).

Insausti *et al.* [1999], while evaluating meat colour stability of different Spanish cattle breeds, stated that the  $L^*a^*b^*C^*$  and  $H^{\circ}$  values of vacuum-packed meat showed distinct growth over the first five days and persisted at the same level till the 15<sup>th</sup> day. Aporta *et al.* [1996], however, evaluating the parameters of colour change CIE  $L^*a^*b^*$  of the LD and ST of calves during the first days after slaughter, observed the values of lightness  $L^*$  to first rise from the 2<sup>nd</sup> to 8<sup>th</sup> day and then to slightly fall on the 9<sup>th</sup> day. A share of a red colour  $a^*$  in this time showed a constant downward tendency. For the LD, the  $L^*$  value increased from 37.2 up to 39.2, whereas  $a^*$  value decreased from 17.3 to 15.4. For the ST, the parameters ranged as follows:  $L^*$  – from 42.9 up to 43.5; value  $a^*$  –

16.0–12.1, respectively. McKenna *et al.* [2005] assessed discoloration characteristics of 19 bovine muscles during 5 days of storage and found very subtle changes in  $L^*$ -values. The highest  $L^*$ -values had *M. semitendinosus* and *M. tensor fasciae latae*, whereas *M. longissimus lumborum*, *M. longissimus thoracis*, and *M. triceps brachii* had the lowest mean  $L^*$ -values.

The texture or tenderness makes the basic qualitative parameter and most probably the crucial one for a consumer of the red meat. The evaluation of LL and ST meat tenderness expressed with shearing force (Table 1) did not show any influence of sex on this parameter, while a decrease of SF value had a significant impact on the conditioning time. Tenderness of young bulls meat showed a substantial significant improvement, which for the ST was determined after 7 days and for the LL after 14 days of the conditioning period (Figure 3).

The American studies [Berry, 1993] report that a consumer is sure of getting the loin steaks of suitable tenderness (meat after thermal processing) if the shear force W-B does not exceed 3.9 kg value. However, Shackelford *et al.* [1991] claim that the W-B threshold value for commercial beef is 4.6 kg. Boleman *et al.* [1997] suggested the following categories for beef steaks on the grounds of the W-B force: tender from 2.27 up to 3.58 kg, moderate 4.08–5.40 kg and tough 5.90–7.21 kg. According to this division, the ultimate LL and ST tenderness shown in the present studies implies that it belongs to the tender category.

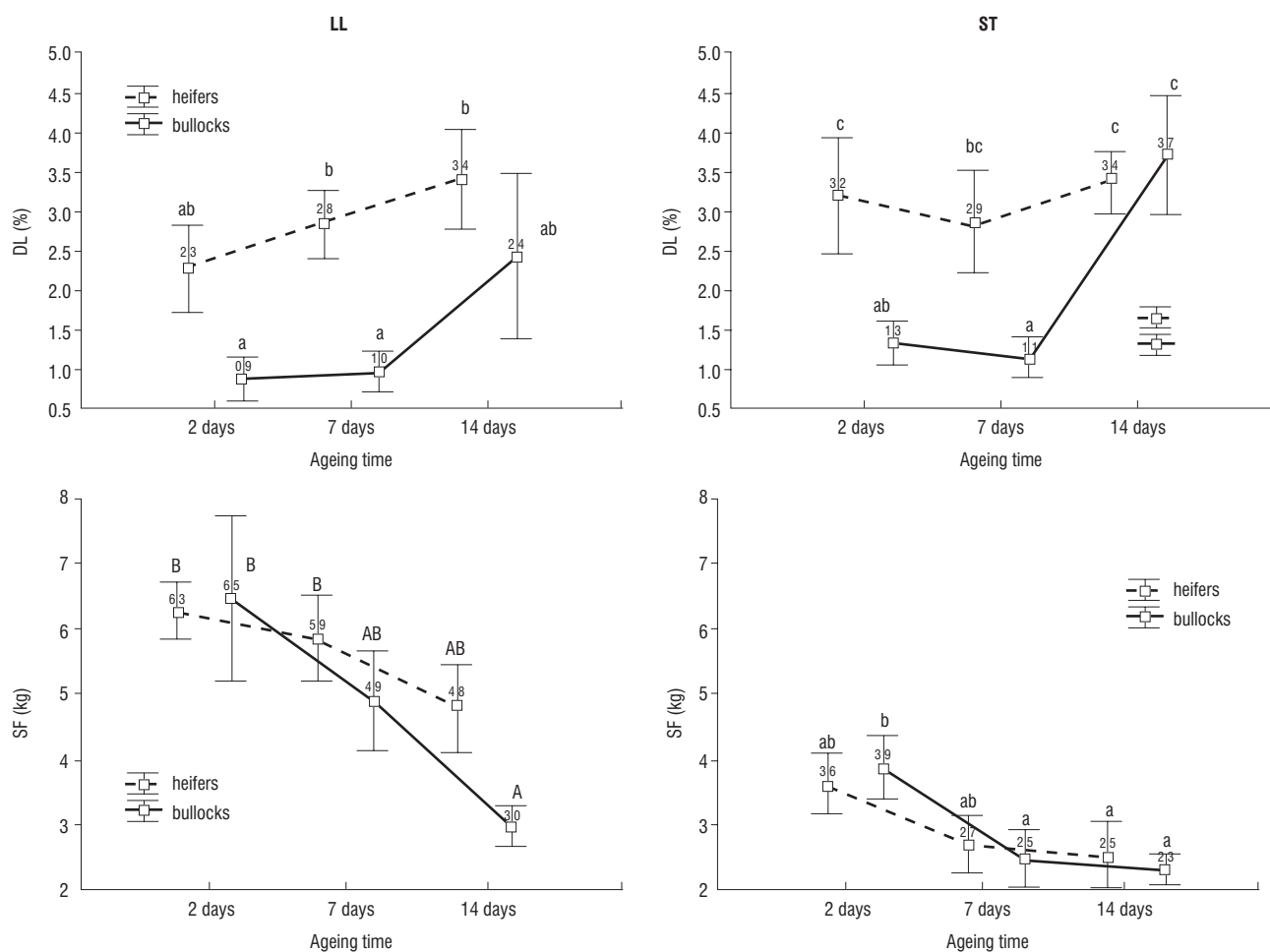


FIGURE 3. Changes of drip loss and shear force of beef muscles depending on sex and ageing time (mean  $\pm$  SE). A, B – for each muscle means bearing different superscript differ significantly at  $p < 0.01$ . a, b, c – for each muscle means bearing different superscript differ significantly at  $p < 0.05$ .

Higher LD tenderness of meat obtained from the heifers and stored at 4°C was observed by Byrne *et al.* [2000]. These authors claim that shearing force W-B assessed on the 2<sup>nd</sup> day after slaughter was 7.21 kg, which decreased to 5.08 kg after 7 days and was only 3.80 kg after 14 days. Significant improvement of tenderness (lowered shearing force) of bovine muscles (*longissimus dorsi*, *semimembranosus*) after vacuum storage was also stated by Maher *et al.* [2004] and Oliete *et al.* [2006]. Gerhardy [1995] did not note any differences in LD and ST tenderness between heifers and young bulls after the thermal treatment at 75°C, yet higher tenderness (low shearing force) was recorded for LD. Braghieri *et al.* [2005], though, did not find any significant influence of the ageing time on LD tenderness improvement.

The Warner-Bratzler method gives the maximal force needed to shear a sample of meat, no information on perception of meat tenderness during biting and mastication can be detected. Girolami *et al.* [2003] stated that sensory evaluation of meat may be more effective in detecting subtle tenderness differences than the instrumental assessment.

The amount of drip loss from raw beef is influenced by the following factors: age, sex, diet, pre-slaughter stress, slaughter method, storage time and temperature and such meat properties as pH and intramuscular moisture and fat content [Lawrie, 1991].

A significantly lower natural drip was shown in the bulls muscles as compared to heifers. There was observed a steady

increase of the LL muscle natural drip during the conditioning time (2, 7 and 14 days) but the differences were insignificant. The significant growth on the 14<sup>th</sup> day was observed in the ST muscle (Table 1). Analysing the natural drip changes in the examined muscles subject to sex, there was noted significantly lower LL muscle loss in the bulls on the 7<sup>th</sup> day as against the heifers, in the ST muscle the differences appeared on the 2<sup>nd</sup> and 7<sup>th</sup> ageing day (Figure 3).

Sekar *et al.* [2006] found a similar, like in the present investigations, constant drip growth for the vacuum-stored *m. quadriceps femoris* on the 3<sup>rd</sup>, 7<sup>th</sup>, 14<sup>th</sup> and 21<sup>st</sup> day, that was 1.43, 2.15, 2.99 and 3.89%, respectively. Garssen *et al.* [1995], while evaluating the natural drip from vacuum-stored *m. longissimus lumborum* from the bulls of Friesian breed, proved that on the 5<sup>th</sup> day it reached 5.57%, whereas on the 10<sup>th</sup> day it went up to 6.93%.

## CONCLUSIONS

There was demonstrated a significant influence of sex on pH, colour ( $a^*$  and  $b^*$  values) and natural drip loss from the LL and ST muscle. Over the 14 days conditioning period, tenderness improved significantly along with steady growth of specific electrical conductivity of the evaluated muscles. The meat of heifers aged for 14 days under vacuum was characterised by lower pH, higher specific electrical conductivity, greater natural drip as well more red colour (higher  $a^*$ ) and yellow (higher  $b^*$ ) as compared to the meat of young bulls.



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## ZMIANY WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH MIĘSA BUHAJKÓW I JAŁÓWEK W OKRESIE 14 DNIOWEGO DOJRZEWANIA PRÓŻNIOWEGO

*Mariusz Florek, Anna Litwińczuk, Piotr Skąlecki, Małgorzata Ryszkowska-Siwko*

*Katedra Oceny i Wykorzystania Surowców Zwierzęcych, Akademia Rolnicza, Lublin*

Celem pracy była ocena wpływu czasu dojrzewania (w okresie 14 dniowego przechowywania próżniowego) i płci (jałowki vs. buhajki) na właściwości fizykochemiczne dwóch mięśni szkieletowych. Materiałem badawczym były losowo pobrane próby mięśnia najdłuższego grzbietu (odcinek lędźwiowy) – LL i półścięgnistego uda – ST z tusz buhajków (n=12) i jałówek (n=12), w wieku około 18 miesięcy rasy Polski Holsztyno-Fryz odmiany czarno-białej. W próbach oznaczono pH, przewodność elektryczną właściwą – EC (mS/cm), wartości CIE L\*a\*b\*, siłę cięcia i wyciek naturalny. Wykazano istotny wpływ płci na pH, barwę (a\* i b\*) oraz wyciek naturalny mięśnia LL i ST (tab. 1). W czasie 14 dni dojrzewania istotnie poprawiała się kruchość i występował stały wzrost przewodności elektrycznej właściwej ocenianych mięśni. Mięso jałówek w czasie 14 dni przechowywania próżniowego charakteryzowało się niższym pH, wyższą przewodnością elektryczną właściwą (rys. 1), większym wyciekem naturalnym (rys. 3) oraz było bardziej czerwone (wyższe a\*) i żółte (wyższe b\*) w porównaniu do mięsa buhajków (rys. 2).

