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THE EFFECT OF CATTLE GENOTYPE ON TEXTURE OF SELECTED MUSCLES DURING POST-MORTEM AGEING

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ABSTRACT

Changes in textural parameters of selected muscles (*m. longissimus lumborum* – LL, *m. semitendinosus* – ST, *m. semimembranosus* – SM, *m. biceps femoris* – BF) of pure-breed cattle Charolaise (CHL) and two groups of cross breeds: Hereford×Charolaise (HEF×CHL) and Simental×Charolaise (SIM×CHL) taken on the 3rd, 7th and 12th day of post-mortem cold storage were estimated.

Of the four muscles tested, the highest hardness, springiness and chewiness were found in BF, which at the same time showed the highest stringiness, perceptible of connective tissue, cooking loss, and the lowest juiciness. Post mortem ageing resulted in a reduction of hardness, springiness and cooking loss and in an increase of tenderness and purge loss. The rate and dimension of tenderization were relative to the both cattle genotype and muscle tested on the one side, and stage of tenderization on the other.

Key words: texture, muscles, young bulls, ageing

INTRODUCTION

The eating quality of beef (*i.a.* texture, tenderness, chemical composition) is related to the both ante- and post-mortem factors. Of the ante-mortem factors tested, the most important is an animal breed selection, which could be connected, for example, owing to cross-breeding programs, with meat quality [5]. A meat tenderness could have been achieved during post-mortem ageing. In case of cattle it is a long lasting period, and tenderization process is estimated to the end even 2 weeks after slaughter. Post-mortem ageing of meat is connected with a proteolysis of myofibrils and connective tissue [8, 15, 22].

Proteolytic degradation of there proteins would cause texture changes, and, thus tenderization. However, the rate of tenderization could be correlated with many factors *i.a.* with a cattle breed and the muscle tested. The different susceptibility of the muscles or meat of different animal breeds could have been caused by *i.a.* different contents of connective tissue, and an activity of proteolytic enzymes – calpain and calpastatin on the one hand [25], different contents of red and white fibres in the muscles under consideration on the other [24]. It can be thus assumed that the properly genetic selection in beef production will allow to obtain meat of high eating quality (tenderness).

AIM OF THE STUDY

The study presented here was aimed at comparing changes of texture of selected muscles from Charolaise pure breed cattle and their crosses with Hereford and Simental breeds during post-mortem ageing.

MATERIAL AND METHODS

The study involved 3 groups of cattle of following genotypes:

1. group: ♀ CHL x ♂ CHL
2. group: ♀ HEF x ♂ CHL
3. group: ♀ SIM x ♂ CHL,

where: CHL – Charolaise breed, HEF-Hereford breed, SIM-Simental breed

Eight bulls of each group were examined. An investigation have been done at private stock-farm in Wyszobór. The young bulls were managed at their mothers in pasture system. All of them were born in early spring (March, April). Mother’s milk and green forage from pasture (additionally, at night, a hay and protein food) was fed during a rearing period. During the fattening period the young bulls were allowed a fattening diet (a grass and maize ensilage with a small quantity of cereal mix – a barley, oat and wheat rye). Body weight gain of the animals, of about 850.g daily, were recorded. Animals were slaughtered at the mass of 550kg at the experimental station. The bulls were transported to the slaughterhouse of Meat Processing Plant of Agrofirma Witkowo, and then were starved by about 12 h prior to slaughtering. A left hindquarters of carcass, kept at the cold room for 12 h served to obtain 4 muscles:

- LL – *m. longissimus lumborum*,
- ST – *m. semitendinosus*,
- SM – *m. semimembranosus*,
- BF – *m. biceps femoris*.

About 4 cm thick slices were cut perpendicularly to the fibres from each muscle. Each slice, after weighing, was vacuum packaged in plastic bags and cold stored 4±1°C. The samples were taken for assays on the 3rd, 7th and 12th day of *post mortem (p.m.)* cold storage.

After removal of the plastic bags, the pH was measured with a pH-meter CP-215. After weighing, samples were tightly wrapped in thermoresistant plastic bags, and cooked in water at 80°C until the geometric centre of a sample was heated to 70°C. The cooked samples were cooled to 15°C, re-weighed, wrapped in plastic sheet and cold stored until the analysis were made. Before the texture assays were made, 20±1mm thick slices were cut from each muscle with an electric knife Siemens.

An instrumental texture assays
The texture was evaluated on an Instron 1140 apparatus, using the TPA double squeeze test. The test involved driving a 6.2 mm diameter shaft twice into a sample down to 80% of its height, pararell to the fibres; the force was applied at a speed of 50 mm/min. The force-deformation curve obtained served to calculate meat hardness, cohesiveness, springiness and chewiness [2]. The procedure was repeated 9 times on each sample batch.

The sensory texture evaluation

The sensory evaluation of the beef samples was assessed by a trained expert panel of 4 members with, in general, a minimum of four years experience in texture analysis of meat and meat products. The meat tenderness, juiciness, perceptible of connective tissue and stringiness were assessed using a 5-points scale (Table 1).

Table 1. The 5-points sensory evaluation scale

Traits	**1 point**	**2 points**	**3 points**	**4 points**	**5 points**
Tenderness	the toughest	tough	average tough	tender	the most tender
Juiciness	the most dry	dry	average dry	juicy	the most juicy
Perceptible of connective tissue	very abundant	easy perceptible	average perceptible	weakly perceptible	imperceptible
Stringiness	the most stringy	easy perceptible	average perceptible	weakly perceptible	imperceptible

The calculation of purge and cooking losses

Purge loss (%) was calculated from the difference in weight before and after post-mortem ageing. Cooking loss (%) was calculated from the difference in weight before and after thermal treatment.

Statistical treatment

All the calculations were performed with Statistica v.6.0 PL software. A mean and standard deviation was calculated for each samples. A significance of differences was explored by applying Student's *t* test at P = 0.05.

RESULT AND DISCUSSION

Table 2 presents the textural parameters of four beef muscles (of the three cattle groups) after 3rd, 7th and 12th days of post-mortem ageing. A comparison between textural parameters of beef (an arithmetical means of 4 muscles) showed no significant differences in TPA parameters between 3 groups of cattle in any post-mortem ageing period tested. However, the muscle samples of Charolaise pure-breed taken on the 3rd and 7th day ageing showed the highest hardness, cohesiveness, springiness and chewiness. Whereas, meat of SIM×CHL cross-breeds was the toughest, the most cohesiveness, springy and chewy after 12th days of ageing. The sensory texture evaluation showed no significant differences in parameters tested between groups of cattle (Table 3). Among the 3 groups of animals, of the all ageing period tested, CHL meat was characterized by the highest tenderness, the highest juiciness being recorded in HEF×CHL crosses meat, muscles of SIM×CHL showed the lower degree of connective tissue perceptible. The technological properties (pH, purge and cooking losses) showed no significant differences between meat of bulls tested, too (Table 4). Regardless of the ageing time, the highest pH values, and cooking loss were recorded in the SIM×CHL crosses meat, the lowest values being typical of the HEF×CHL crosses muscles.

No differences in meat quality (*i.a.* texture, technological properties) of different cattle groups was reported also by Maher et al. [12], and Chambaz et al. [5]. While Monson et al. [14] showed the differences in hardness between cattle breeds only for LD muscle on 1st, 3rd, and 7th day post-mortem, and next on 14th day of ageing, no differences. The differences between results obtained by those authors and Monson et al. [14] could have been probably caused by differences in experimental materials. A higher differences in meat quality may have resulted from a comparison of pure-breeds [14, 17] than during a comparison pure-breed cattle with their crosses [13] as well as a comparison between cattle types of the same breed [12].

According to Belew et al. [1] and Maher et al. [12], the differences in eating quality of beef may have resulted from differences between breeds, as well as between genotype groups or within an animal carcass. Numerous authors [1, 3, 6, 17] found bovine muscle to differ in terms of hardness. The results of the analyses performed show that of the four muscles tested, regardless of the cattle genotype on the one hand, and ageing time on the other, the highest hardness, springiness, chewiness and stringiness were typical of the BF (Table 2), which at the same time was characterized by the lowest juiciness, the highest perceptible of connective tissue (Table 3) and purge and cooking losses (Table 4). Whereas LL, ST and SM muscles were intermediate in terms of their textural and technological properties. A similar texture ordering of animals muscles was reported by Wheeler et al. [26, 27], and Torrescano et al. [23] for cattle, Sobczak et al. [21], Lachowicz et al. [10] for pigs muscles, whereas for wild boars muscles by Lachowicz et al. [11].

Table 2. Mean values of textural parameters of 4 bovine muscles according to cattle genotype and ageing period

	♀ CHL x ♂ CHL					♀ HEF x ♂ CHL					♀ SIM x ♂ CHL				
	LL	ST	SM	BF	$\bar{x}$	LL	ST	SM	BF	$\bar{x}$	LL	ST	SM	BF	$\bar{x}$
Samples after 3 days of ageing															
Hardness (N)	60.22^{a}_{1}	63.12^{ab}_{1}	70.52^{b}_{1}	89.81^{c}_{1}	***70.92***	61.74^{a}_{1}	64.66^{a}_{1}	70.10^{b}_{1}	72.58^{b}_{2}	***67.27***	67.56^{ab}_{1}	64.19^{a}_{1}	66.16^{ab}_{1}	71.54^{b}_{2}	***67.36***
Cohesiveness (-)	0.516^{ab}_{1}	0.546^{b}_{1}	0.517^{ab}_{1}	0.476^{c}_{1}	***0.514***	0.444^{a}_{2}	0.473^{ab}_{2}	0.430^{a}_{2}	0.531^{b}_{1}	***0.470***	0.520^{a}_{1}	0.490	0.490^{a}_{1}	0.480^{a}_{1}	***0.495***
Springiness (cm)	1.19^{a}_{1}	1.28^{b}_{1}	1.25^{ab}_{1}	1.40^{c}_{1}	***1.28***	1.10^{a}_{1}	1.20^{b}_{1}	1.16^{ab}_{1}	1.30^{c}_{2}	***1.19***	1.14^{a}_{1}	1.32^{b}_{1}	1.26^{b}_{1}	1.34^{b}_{2}	***1.26***
Chewiness (N×cm)	37.29^{a}_{1}	44.11^{b}_{1}	45.22^{b}_{1}	60.49^{c}_{1}	***46.78***	30.15^{a}_{2}	36.70^{a}_{2}	35.71^{a}_{2}	50.09^{b}_{2}	***38.16***	40.54^{a}_{1}	41.02^{a}_{1}	40.85^{a}_{1}	46.01^{a}_{2}	***42.10***
Samples after 7 days of ageing															
Hardness (N)	53.94^{a}_{1}	58.22^{a}_{1}	58.54^{a}_{1}	81.03^{b}_{1}	***62.93***	55.94^{a}_{1}	58.59^{a}_{1}	56.53^{a}_{1}	69.95^{b}_{2}	***60.25***	59.73^{a}_{1}	61.45^{a}_{1}	57.98^{a}_{1}	65.21^{a}_{2}	***61.09***
Cohesiveness (-)	0.506^{a}_{1}	0.524^{a}_{1}	0.456^{b}_{1}	0.506^{a}_{1}	***0.498***	0.453^{a}_{2}	0.541^{b}_{1}	0.520^{b}_{2}	0.428^{a}_{2}	***0.486***	0.494^{a}_{1}	0.539^{a}_{1}	0.535^{a}_{2}	0.506^{a}_{1}	***0.518***
Springiness (cm)	1.10^{a}_{1}	1.23^{b}_{1}	1.23^{b}_{1}	1.22^{b}_{1}	***1.20***	1.06^{a}_{1}	1.18^{bc}_{1}	1.14^{b}_{2}	1.26^{c}_{1}	***1.16***	1.11^{a}_{1}	1.28^{b}_{2}	1.24^{b}_{1}	1.24^{b}_{1}	***1.22***
Chewiness (N×cm)	29.63^{a}_{1}	37.40^{b}_{1}	32.68^{ab}_{1}	50.02^{c}_{1}	***37.43***	29.98^{a}_{1}	37.40^{b}_{1}	33.68^{ab}_{1}	37.72^{b}_{2}	***34.70***	30.00^{a}_{1}	42.27^{b}_{1}	38.46^{b}_{1}	40.92^{b}_{2}	***37.91***
Samples after 12 days of ageing															
Hardness (N)	52.64^{a}_{1}	52.48^{a}_{1}	50.54^{a}_{1}	68.32^{b}_{1}	***56.00***	55.23^{a}_{1}	54.66^{a}_{1}	51.89^{a}_{1}	58.61^{a}_{2}	***55.10***	58.52^{a}_{1}	55.36^{a}_{1}	52.20^{a}_{1}	$61.26^{a}_{1,2}$	***56.84***
Cohesiveness (-)	0.454^{a}_{1}	0.462^{a}_{1}	0.508^{b}_{1}	0.432^{a}_{1}	***0.464***	0.441^{a}_{1}	0.474^{a}_{1}	0.499^{a}_{1}	0.480^{a}_{1}	***0.474***	0.475^{ab}_{1}	0.524^{b}_{2}	0.437^{a}_{2}	0.473^{ab}_{1}	***0.477***
Springiness (cm)	1.03^{a}_{1}	1.22^{b}_{1}	1.07^{a}_{1}	1.16^{b}_{1}	***1.12***	1.05^{a}_{1}	1.16^{b}_{1}	1.01^{a}_{1}	1.14^{b}_{1}	***1.09***	1.06^{a}_{1}	1.24^{b}_{1}	1.17^{b}_{2}	1.17^{b}_{1}	***1.16***
Chewiness (N×cm)	25.22^{a}_{1}	29.58^{ab}_{1}	27.63^{a}_{1}	33.84^{b}_{1}	***27.07***	25.57^{a}_{1}	30.05^{ab}_{1}	26.15^{a}_{1}	32.07^{b}_{1}	***28.46***	28.97^{ab}_{1}	35.97^{c}_{1}	26.69^{a}_{1}	33.90^{bc}_{1}	***31.38***

a, b - samples in a rows, denoted by different letters, were significantly different within a breed ($P \le 0.05$);
1,2 - samples in a rows, denoted by different numerals, were significantly different between breeds ($P \le 0.05$)

Table 3. Mean values of sensory attributes of 4 bovine muscles according to cattle genotype and ageing period

	♀ CHL x ♂ CHL					♀ HEF x ♂ CHL					♀ SIM x ♂ CHL				
	LL	ST	SM	BF	$\overline{X}$	LL	ST	SM	BF	$\overline{X}$	LL	ST	SM	BF	$\overline{X}$
Samples after 3 days of ageing															
Tenderness (points)	2.4^{a}_{1}	3.5^{b}_{1}	3.2^{b}_{1}	2.2^{a}_{1}	***2.82***	2.6^{a}_{1}	3.0^{a}_{1}	3.0^{a}_{1}	2.5^{a}_{1}	***2.78***	2.8^{a}_{1}	3.0^{a}_{1}	2.7^{a}_{1}	2.3^{a}_{1}	***2.70***
Juiciness (points)	3.2^{a}_{1}	4.0^{b}_{1}	2.2^{c}_{1}	2.2^{c}_{1}	***2.90***	3.2^{a}_{1}	2.5	2.5^{b}_{1}	3.5^{a}_{2}	***2.92***	2.7^{a}_{1}	2.8^{a}_{2}	2.7^{a}_{1}	2.5^{a}_{1}	***2.68***
Perceptible of connective tissue (points)	3.2^{a}_{1}	3.0^{a}_{1}	2.5^{a}_{1}	2.5^{a}_{1}	***2.80***	3.5^{a}_{1}	2.5^{b}_{1}	2.8^{b}_{1}	2.8^{b}_{1}	***2.90***	2.8^{a}_{1}	2.5^{a}_{1}	2.5^{a}_{1}	2.0^{a}_{1}	***2.45***
Stringiness (points)	3.2^{a}_{1}	3.0^{a}_{1}	3.0^{a}_{1}	3.0^{a}_{1}	***3.05***	3.8^{a}_{2}	3.0^{b}_{1}	2.5^{b}_{1}	3.0^{b}_{1}	***3.08***	2.8^{a}_{1}	3.0^{a}_{1}	3.2^{a}_{1}	2.7^{a}_{1}	***2.92***
Samples after 7 days of ageing															
Tenderness (points)	2.8^{a}_{1}	3.8^{b}_{1}	3.5^{b}_{1}	2.4^{a}_{1}	***3.12***	2.7^{a}_{1}	3.8^{b}_{1}	3.1^{a}_{1}	2.8^{a}_{1}	***3.10***	3.0^{a}_{1}	3.3^{a}_{1}	3.0^{a}_{1}	2.5^{a}_{1}	***2.95***
Juiciness (points)	2.2^{a}_{1}	3.8^{bc}_{1}	2.8^{ac}_{1}	3.2^{c}_{1}	***3.00***	3.8^{a}_{2}	3.0^{b}_{2}	2.8^{b}_{1}	4.0^{a}_{2}	***3.40***	3.0^{a}_{1}	$3.3^{a}_{1,2}$	2.8^{a}_{1}	3.3^{a}_{1}	***3.10***
Perceptible of connective tissue (points)	2.2^{a}_{1}	3.5^{b}_{1}	3.0^{b}_{1}	3.0^{b}_{1}	***2.92***	2.5^{a}_{1}	$3.0^{a}_{1,2}$	2.8^{a}_{1}	2.2^{a}_{2}	***2.62***	3.7^{a}_{2}	2.7^{b}_{2}	3.0^{b}_{1}	3.5^{ab}_{1}	***3.22***
Stringiness (points)	3.0^{a}_{1}	3.2^{a}_{1}	2.5^{a}_{1}	3.0^{a}_{1}	***2.92***	3.2^{a}_{1}	3.2^{a}_{1}	2.8^{a}_{1}	3.5^{a}_{1}	***3.18***	3.3^{a}_{1}	3.3^{a}_{1}	3.2^{a}_{1}	3.0^{a}_{1}	***3.20***
Samples after 12 days of ageing															
Tenderness (points)	3.2^{a}_{1}	4.0^{b}_{1}	4.0^{b}_{1}	2.6^{a}_{1}	***3.45***	3.1^{a}_{1}	4.0^{b}_{1}	3.2^{a}_{2}	3.0^{a}_{2}	***3.32***	3.2^{a}_{1}	3.3^{a}_{2}	3.2	2.6^{a}_{1}	***3.08***
Juiciness (points)	3.0^{a}_{1}	3.0^{a}_{1}	$3.5^{a}_{1,2}$	3.0^{a}_{1}	***3.12***	3.0^{a}_{1}	3.5^{ab}_{1}	4.0^{b}_{2}	3.0^{a}_{1}	***3.38***	3.2^{a}_{1}	3.0^{a}_{1}	3.3^{a}_{1}	2.8^{a}_{1}	***3.08***
Perceptible of connective tissue (points)	$2.0^{a}_{1,2}$	3.5^{b}_{1}	3.5^{b}_{1}	2.5^{a}_{1}	***2.88***	2.5^{a}_{2}	3.5^{b}_{1}	4.0^{b}_{1}	3.5^{b}_{2}	***3.38***	2.7^{a}_{2}	2.8^{a}_{2}	2.8^{a}_{2}	2.5^{a}_{1}	***2.70***
Stringiness (points)	3.0^{a}_{1}	4.0^{b}_{1}	2.0^{c}_{1}	2.5^{ac}_{1}	***2.88***	3.0^{a}_{1}	$3.5^{a}_{1,2}$	3.5^{a}_{2}	3.0^{a}_{1}	***3.25***	3.2^{a}_{1}	3.0^{a}_{2}	3.3^{a}_{2}	3.2^{a}_{1}	***3.18***

a, b - samples in a rows, denoted by different letters, were significantly different within a breed ($P \leq 0.05$);
1,2 - samples in a rows, denoted by different numerals, were significantly different between breeds ($P \leq 0.05$)

Table 4. Mean values of pH, purge and cooking loss of 4 bovine muscles according to cattle genotype and ageing period

	♀ CHL x ♂ CHL					♀ HEF x ♂ CHL					♀ SIM x ♂ CHL				
	LL	ST	SM	BF	$\overline{X}$	LL	ST	SM	BF	$\overline{X}$	LL	ST	SM	BF	$\overline{X}$
Samples after 3 days of ageing															
pH	5.57^{a}_{1}	5.60^{a}_{1}	5.54^{a}_{1}	5.54^{a}_{1}	***5.56***	5.58^{a}_{1}	5.52^{a}_{1}	5.49^{a}_{1}	5.51^{a}_{1}	***5.52***	5.65^{a}_{1}	5.63^{a}_{1}	5.55^{a}_{1}	5.57^{a}_{1}	***5.60***
Purge loss (%)	1.74^{a}_{1}	1.97^{a}_{1}	2.16^{a}_{1}	2.64^{a}_{1}	***2.13***	1.94^{a}_{1}	2.68^{a}_{1}	2.48^{a}_{1}	2.92^{a}_{1}	***2.51***	1.41^{a}_{1}	1.78^{a}_{1}	1.98^{a}_{1}	2.56^{a}_{1}	***1.93***
Cooking loss (%)	22.70^{a}_{1}	28.92^{ab}_{1}	28.05^{ab}_{1}	33.73^{b}_{1}	***28.35***	24.30^{a}_{1}	28.25^{ab}_{1}	29.80^{ab}_{1}	31.15^{b}_{1}	***28.38***	25.39^{a}_{1}	29.49^{ab}_{1}	30.16^{b}_{1}	30.59^{b}_{1}	***28.91***
Samples after 7 days of ageing															
pH	5.54^{a}_{1}	5.56^{a}_{1}	5.55^{a}_{1}	5.54^{a}_{1}	***5.55***	5.58^{a}_{1}	5.52^{a}_{1}	5.52^{a}_{1}	5.51^{a}_{1}	***5.53***	5.64^{a}_{1}	5.63^{a}_{1}	5.67^{a}_{1}	5.57^{a}_{1}	***5.63***
Purge loss (%)	2.28^{a}_{1}	3.14^{a}_{1}	2.95^{a}_{1}	3.22^{a}_{1}	***2.90***	3.42^{a}_{1}	3.42^{a}_{1}	3.80^{a}_{1}	3.01^{a}_{1}	***3.41***	3.26^{a}_{1}	3.72^{a}_{1}	4.40^{a}_{1}	3.31^{a}_{1}	***3.67***
Cooking loss (%)	22.44^{a}_{1}	$26.8^{ab}_{1}0$	26.96^{ab}_{1}	30.44^{b}_{1}	***26.66***	22.80^{a}_{1}	26.40^{ab}_{1}	28.20^{ab}_{1}	30.60^{b}_{1}	***27.00***	22.63^{a}_{1}	27.99^{ab}_{1}	27.38^{b}_{1}	28.90^{b}_{1}	***26.73***
Samples after 12 days of ageing															
pH	5.60^{a}_{1}	5.61^{a}_{1}	5.60^{a}_{1}	5.56^{a}_{1}	***5.59***	5.54^{a}_{1}	5.56^{a}_{1}	5.54^{a}_{1}	5.54^{a}_{1}	***5.54***	5.60^{a}_{1}	5.63^{a}_{1}	5.61^{a}_{1}	5.57^{a}_{1}	***5.60***
Purge loss (%)	4.00^{a}_{1}	4.87^{a}_{1}	3.44^{a}_{1}	3.73^{a}_{1}	***4.01***	4.65^{a}_{1}	4.66^{a}_{1}	4.50^{a}_{1}	4.04^{a}_{1}	***4.46***	3.72^{a}_{1}	5.13^{b}_{1}	4.78^{ab}_{1}	3.98^{a}_{1}	***4.40***
Cooking loss (%)	20.71^{a}_{1}	20.30^{a}_{1}	22.53^{a}_{1}	24.12^{a}_{1}	***21.92***	18.40^{a}_{1}	19.40^{a}_{1}	21.85^{a}_{1}	28.83^{b}_{1}	***22.12***	21.21^{a}_{1}	25.35^{a}_{1}	26.44^{a}_{1}	27.15^{a}_{1}	***25.04***

a, b - samples in a rows, denoted by different letters, were significantly different within a breed ($P \leq 0.05$);
1,2 - samples in a rows, denoted by different numerals, were significantly different between breeds ($P \leq 0.05$)

According to Koohmaraie et al. [9], sarcomere length, connective tissue content, and proteolysis of myofibrillar proteins account for most of the explainable variation observed in tenderness of aged meat, after post-mortem storage. For example, while sarcomere length is the major determinant of PM muscle tenderness, connective tissue content is a major contributor to tenderness of BF muscle and proteolysis is the major determinant of L tenderness. Therefore, a similar hardness of LL, ST and SM muscles may have resulted from *i.a.* no differences in amounts and thickness of connective tissue in muscles. As shown by Brooks and Savell [3] muscles with thicker perimysium had a higher shear force. According to Wheeler et al. [26], BF is characterized by the most abundant connective tissue compared to other muscles tested – which at the same time, as shown in this work, was the toughest muscle; the lower amount of connective tissue being typical of the SM muscle, and the lowest was recorded in the LL.

The prolonged storage of meat from 3-7 days (the first stage of ageing), and the next from 7-12 days (the second stage of ageing) caused a decrease of hardness, springiness, chewiness and cooking losses and an increase in tenderness, juiciness and purge loss. The differences in mean values of parameters tested changes were dependent on both cattle genotype and kind of muscle on the one hand, and the stage of ageing on the other. No significant effects of ageing time on cohesiveness, perceptible of connective tissue, stringiness and pH changes were found.

Among the animal groups tested, the higher hardness, springiness and chewiness changes of CHL pure-breed meat were found at the first (between 3-7 days of cold storage) and the second (between 7-12 days) stage of ageing. The meat of cross-breeds animals was characterized by the higher susceptibility to tenderness, juiciness, purge and cooking loss changes during first stage of ageing, whereas CHL meat was more susceptible to changes at second stage of ageing.

Regardless of the cattle group, of all the muscles tested, the most susceptible to hardness, springiness and chewiness changes were BF and SM. However the higher changes of those parameters values were observed in SM at the first stage of ageing, and at the second stage in BF. The lowest hardness and chewiness changes were recorded in the LL, whereas the lowest springiness changes being typical of the ST. No effects of muscle on sensory parameters, as well as purge and cooking losses changes during ageing were found.

A similar effect of ageing time on muscle texture was reported by *i.a.* Koohmaraie et al. [9], Kołczak et al. [7], Palka [18], Brooks and Savell [3], Maher et al. [12], Monson et al. [14]. The data obtained show the rate and dimension of tenderization were dependent on muscle type, cattle genotype and ageing time. A comparison between the dimension of tenderization of four muscles showed the harder muscles (BF and SM) were the most susceptible to hardness changes. Kołczak et al. [7] demonstrated that the lower rate of tenderization being typical of the most tender muscle – PM, compared to harder ST muscle, whereas Hwang et al. [6] found that LD was characterized by reduced post-mortem proteolysis compared to ST muscle.

Of the cattle groups tested, the muscles of pure-breed bulls showed initially the highest hardness (at 3rd day post-mortem), and were the most susceptible to hardness changes; it is conformable to Sañudo et al. [20] and Monson et al. [14] research, who observed the bovine muscles of higher hardness to be more susceptible to hardness changes during ageing. Moreover, according Maher et al. [12], meat from double-muscle Charolaise cattle with higher hardness become more tender during first stage of ageing (2-7 days), while the cattle with normal muscles during second stage (between 7th and 12th day) of ageing. However, Monson et al. [14] is of the opinion that the meat from cattle of initially lower hardness is more susceptible to tenderization during first stage of ageing, while during the second stage more susceptible are breeds with muscles of higher hardness, but no significant differences between bovine muscles susceptible to hardness reduction during 21st and 35th day of ageing were found. According to Campo et al. [4], the animal breed is the minor determinant to tenderness of muscles, and the major contributor to tenderness is the ageing time. As shown in this work, regardless of both cattle genotype and muscle type, a higher hardness and tenderness changes were found between 3rd and 7th day (the first stage) than between 7th and 12th day (the second stage) of ageing. Similar observation were reported by Koohmaraie et al. [9], who observed the highest decrease of shear force between 1st and 3rd day post-mortem, while the reduction of shear force was insignificant between 3rd and 14th day of ageing. However Ruiz de Huidobro et al. [19] found no correlation between ageing time and drip loss, shear force or texture of L muscle, but a decrease at first stage of ageing and an increase at second stage of those parameters were observed.

CONCLUSIONS

The result obtained show no significant differences in meat eating quality between the three groups of cattle tested. However, the pure-breed CHL cattle meat, compared to the HEF×CHL and SIM×CHL crosses were characterized by the insignificant higher hardness, springiness and chewiness. Regardless of the young bulls genotype, among the four muscle tested, the highest values of hardness, springiness and chewiness were recorded in BF, which at the same time showed the lower, juiciness as well as the higher stringiness and the highest perceptible of connective tissue and purge and cooking losses. No significant differences in textural parameters and technological properties between LL, ST and SM were found.

Post-mortem ageing resulted in a reduction of muscle hardness, springiness, cooking loss and an increase of tenderness and purge loss, however the rate and dimension of tenderization were dependent on cattle genotype, muscle type and ageing time. Of the cattle groups tested, the muscles of CHL pure-breed bulls were the most susceptible to tenderization, and of the muscles tested – BF and SM. As shown in this work, a higher hardness changes were found at the first stage than at the second stage of ageing. An ageing process, as a result of a higher susceptibility on tenderization of muscles with a higher initially hardness, caused a decrease in hardness differences between muscles tested on the one hand, and between groups of cattle on the other.

REFERENCES

1. Belew J. B., Brooks J. C., Mckenna D. R., Savell J. W., 2003. Warner-Bratzler shear evaluations of 40 bovine muscles. Meat Sci. 64, 507-512.
2. Bourne M. C., 1982. Food texture and viscosity: concept and measurement. Academic Press, New York.
3. Brooks J. C., Savell J. W., 2004. Perimysium thickness as an indicator of beef tenderness. Meat Sci. 67, 329-334.
4. Campo M. M., Santolaria P., Sañudo C., Lepetit J., Olleta J. L., Panea B., Alberti P., 2000. Assessment of breed type and ageing time effects on beef meat quality using two different texture devices. Meat Sci. 55, 371-378.
5. Chambaz A., Kreuzer M., Scheeder M. R. L., Dufey P.A., 2001. Characteristics of steers of six beef breeds fattened from eight months of age and slaughtered at a target level of intramuscular fat. II. Meat quality. Arch. Tierz., Dummerstorf, 44/5, abstract.
6. Hwang I. H., Park B. Y., Cho S. H., Lee J. M., 2004. Effects of muscle shortening and proteolysis on Warner-Bratzler shear force in beef *longissimus* and *semitendinosus*. Meat Sci. 68, 497-505.
7. Kołczak T., Pospiech E., Palka K., Łącki J., 2003. Changes of myofibrillar and centrifugal drip proteins and shear force of *psoas major* and *minor* and *semitendinosus* muscles from calves, heifers and cows during post-mortem ageing. Meat Sci. 64, 69-75.
8. Koohmaraie M., 1996. Biochemical factors regulating the toughening and tenderization processes of meat. Meat Sci. 43, 193-201.
9. Koohmaraie M., Kent M. P., Shackelford S. D., Veiseth E., Wheeler T. L., 2002. Meat tenderness and muscle growth: is there any relationship. Meat Sci. 62, 345-352.
10. Lachowicz K., Sobczak M., Gajowiecki L., Żych A., 2003. Effects of massaging time on texture, rheological properties, and structure of three pork ham muscles. Meat Sci. 63, 225-233.
11. Lachowicz K., Żochowska J., Sobczak M., 2004. Comparison of the texture and structure of selected muscles of piglets and boar juveniles, Pol. J. Food Nutr. Sci. 1, 13/54, 75-79.
12. Maher S. C., Mullen A. M., Moloney A. P., Drennan M. J., Buckley D. J., Kerry J. P., 2004. Colour, composition and eating quality of beef from the progeny of two Charolais sires. Meat Sci. 67, 73-80.
13. Matuszewska I., Szczecińska A., Radzanowska J., Jesiorowski H., Grodzki H., 1994. Wpływ krzyżówek krów włoskiej oraz polskiej białko-czarnej na jakość sensoryczną mięsa [The effect of an Italian cattle and polish white-black cows crosses on sensory quality of meat]. 25 Ses. Nauk. KTiChZ PAN, Lublin, 242 [in Polish].
14. Monson F., Sañudo C., Sierra I., 2004. Influence of cattle breed and ageing time on textural meat quality. Meat Sci. 68, 595-602.
15. Nishimura T., Hattori A., Takahashi K., 1995. Structural weakening of intramuscular connective tissue during conditioning of beef. Meat Sci. 39, 127-133.
16. Nishimura T., Hattori A., Takahashi K., 1996. Relationship between degradation of proteoglycans and weakening of the intramuscular connective tissue during post-mortem aging of beef. Meat Sci. 42, 251-260.
17. Özlütürk A., Tüzemen N., Yanar M., Esenbuga N., Dursun E., 2004. Fattening performance, carcass traits and meat quality characteristics of calves sired by Charolais, Simmental and Eastern Anatolian Red sires mated to Eastern Anatolian Red dams. Meat Sci. 67, 463-470.
18. Palka K., 2003. The influence of post-mortem ageing and roasting on the microstructure, texture and collagen solubility of bovine semitendinosus muscle. Meat Sci. 64, 191-198.
19. Ruiz de Huidobro F., Miguel E., Onega E., Blàquez B., 2003. Changes in meat quality characteristics of bovine meat during the first 6 days post mortem. Meat Sci. 65, 1439-1446.
20. Sañudo C., Macie E. S., Olleta J. L., Villarroel M., Panea B., Alberti P., 2004. The effects of slaughter weight, breed type and ageing time on beef meat quality using two different texture devices. Meat Sci. 66, 925-932.
21. Sobczak M., Lachowicz K., Czarnecki R., Gajowiecki L., Klemke A., Żochowska J., 2004. Comparative analysis of the susceptibility of selected muscles of Pietrain, Duroc and Polish Large White x Polish Landrace. Pol. J. Food Nutr. Sci. 2, 13/54, 179-184.

22. Takahashi K., 1996. Structural weakening of skeletal muscle tissue during post-mortem ageing: the non-enzymatic mechanism of meat tenderization. Meat Sci. 43, S67-S80.
23. Torrescano G., Sánchez-Escalante A., Giménez B., Roncalés P., Baltrán J. A., 2003. Shear values of raw samples of 14 bovine muscles and their relation to muscle collagen characteristics. Meat Sci. 64, 85-91.
24. Wegner J., Albrecht E., Fiedler I., Teuscher F., Papstein H. J., Ender K., 2000. Growth- and breed-related changes of muscle fiber characteristics in cattle. J. Anim. Sci. 78, 1485-1496.
25. Wheeler T. L., Koohmaraie M., 1994. Prerigor and postrigor changes in tenderness of ovine longissimus muscle. J. Anim. Sci. 72, 1232-1238.
26. Wheeler T. L., Shackelford S. D., Koohmaraie M., 2000. Relationship of beef longissimus tenderness classes to tenderness of gluteus medius, semimembranosus, and biceps femoris. J. Anim. Sci. 78, 2856-2861.
27. Wheeler T. L., Shackelford S. D., Casas E., Cundiff L. V., Koohmaraie M., 2001. The effects of Piedmontese inheritance and myostatin genotype on the palatability of longissimus thoracis, gluteus medius, semimembranosus and biceps femoris. J. Anim. Sci. 79, 3069-3074.

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