Physical attributes, chemical composition and sensory analysis of three muscles from heifers and bulls of Fleckvieh cattle

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Abstract. The objective of this study was to compare the effect of sex on meat quality parameters of the meat of bulls and heifers of the Fleckvieh cattle reared and finished under identical nutritional and management conditions and slaughtered at an identical age of 19 months. Physical meat quality measurements, proximate chemical composition and sensory analyses were performed on *musculus longissimus lumborum, musculus triceps brachii* and *musculus rectus abdominis* from total 23 bulls and heifers. The evaluation of chemical composition shows that the meat from bulls contained less dry matter and intramuscular fat. Lower shear force values as well as lower total collagen contents and higher soluble collagen proportions were measured in heifer samples. When the three different muscles were compared, it appeared that *musculus rectus abdominis* exhibited the highest contents of dry matter and intramuscular fat whereas *musculus triceps brachii* had the highest amount of total collagen and also the highest proportion of soluble collagen. *Musculus longissimus lumborum* contained the highest proportion of protein, the lowest proportion of total collagen and exhibited the lowest shear force value. *Musculus longissimus lumborum* was assessed as the tenderest with the most favourable score for fibrosity and chewiness, *musculus triceps brachii* had the highest score for beef odour intensity and beef flavour intensity and *musculus rectus abdominis*was scored as the juiciest. With the exception of beef odour intensity, the meat from heifers was assessed by the sensory panel as more favourable for all the remaining sensory characteristics assessed.

1. Introduction

The Fleckvieh cattle is a local breed in the Czech Republic whose history dates back to the second half of the 19th century. It is a part of the world population of Fleckvieh cattle breeds with economically sustainable high quality milk and meat production ability. In the past century this dual purpose breed dominated in Czech herds. However, the proportion of this breed in the Czech dairy cattle population has begun to decline in favour of widely expanding beef cattle and highly specialized dairy breed Holstein in the last quarter of the 20th century. Czech consumers traditionally prefer young bulls, thus male individuals slaughtered from 12 to 24 months of age. However heifers no further used in breeding may be used to meat production as well.

Compared to bulls, heifers are popular in some southern and westerns European countries, which is related to more pronounced organoleptic properties of their meat[1].Compared to Holstein, the Fleckvieh cattle has higher feed conversion ratio, killing-out proportion and conformation score[2]. Fleckvieh bulls have relatively low proportions of intramuscular fat and muscle collagen, which are comparable to those observed in French beef breeds[3,4].

The quality of beef is given by a number of factors whereas the most important are considered the properties affecting its tenderness or toughness. Muscles originating from different parts have different textural characteristics[5]. The toughness or tenderness of muscles is affected by the content and structure of connective tissues as well as the characteristics of muscle fibres given to them by their metabolic activity. M*usculus longissimus lumborum* (LL) is the main part of the loin and its activity is related to the movements of the spine. This muscle is one of the largest in the carcass; it has quite homogeneous structure and it is often used as a reference muscle in the evaluation of meat quality. *Musculus triceps brachii* (TB) is a muscle located in the shoulder and is involved in the animal's movement activity. *Musculus rectus abdominis* (RA) is located in the flank part and the muscle itself is also called flank steak. This muscle is also easy to cut off without destroying significantly the carcass. Therefore, it appears to be a suitable alternative to LL[6]. Because the quality parameters of a single muscle cannot be considered as a relevant quality indicator for the whole carcass[7], the objective of the study was to compare physical attributes, chemical composition and sensory profile of three muscles of Fleckvieh bulls and heifers.

2. Material and methods

A feeding trial was performed with heifers and bulls in the experimental unit of the Institute of Animal Science. The animals of 7 months age (12 heifers and 12 bulls) were kept in identical housing conditions and they were fed maize silage, legume silage and lucerne hay with the addition of concentrates and mineral supplements. Animals were housed separately according to sex in two pens with straw bedding. Live weight was measured at regular two week intervals. At the end of the trial, when the target slaughter age of 19 months was achieved, the animals were transported to the experimental slaughterhouse without being fasted and there they were slaughtered at the similar age of 599 days and the live weight of 639 kg on average.

At approximately 48 hours post mortem the dressed carcasses were taken from the cooling room for deboning. Three muscles were taken from each individual: *longissimus lumborum* (LL), *triceps brachii* (TB) and *rectus abdominis* (RA). The samples were labelled and transported in the refrigerator box to the laboratory for further processing. After removal of the subcutaneous fat and epimysium, physical characteristics pH and colour were measured. The pH values were obtained 48 h after slaughter (pH_{48}) using an InoLab pH 730 set (WTW, Weilheim, Germany). Meat colour (*L**, lightness; *a**, redness; *b**, yellowness) was measured at three spots 24 h after slaughter using a portable spectrophotometer (CM-2500d, Minolta, Osaka, Japan). For Warner Bratzler shear force measurements, samples were prepared the same way as for the sensory analysis. Samples of 1 cm^2 in cross section were left at room temperature for approximately 3 hours. The peak force needed to shear the sample across fibres was recorded using an Instron Universal Texture Analyzer 3365 (Instron, Canton, USA) equipped with a Warner-Bratzler shear blade.

The samples intended for chemical analyses were homogenized in a food blender and frozen at −20°C until being analysed. Dry matter content was determined by the method of

oven drying (+105°C) to a constant weight. Dried samples were pulverised using a Grindomix GM 200 knife mill (Retsch, Haan, Germany) and analysed for crude protein (Kjeltec 2400, sampler unit 2460, FOSS Tecator AB, Hoganas, Sweden) and crude fat by extraction with petroleum ether (Soxtec Avanti 2055 manual extraction unit, FOSS Tecator AB, Hoganas, Sweden). The hydroxyproline content was determined according toBergman and Loxley method[8]. Total collagen was calculated as hydroxyproline × 7.25 and soluble collagen as hydroxyproline × 7.52 and expressed as g of collagen per kg of fresh meat[9].Soluble collagen was expressed as a ratio (%) of total collagen content.

Samples for sensory analysis were vacuum packed and aged in a refrigerator for seven days. After that, samples were frozen at -20 °C and stored until being analysed. One day before the analysis, the samples were removed from the freezer and placed in a refrigerator where they were thawed inside a plastic wrap at +4 °C. Then they were cut into 20 mm steaks and grilled on a double-sided glass ceramic contact grill (VCR 6l TL, Fiamma, Aveiro, Portugal) at +200 °C until a final internal temperature of +70 °C measured by a digital temperature probe (AD14TH, Ama-Digit, Kreuzwertheim, Germany) was reached. Immediately afterwards, they were cut into approximately 20 mm cubes while taking care not to use their peripheral parts. The samples were encoded using three-digit numeric codes, placed in closed glasses and stored at +50 °C to serving time. The sensory panel consisted of ten trained assessors which assessed samples in a sensory laboratory individually in testing booths and using a red light to obscure meat colour. The test used a quantitative descriptive method. Six "sets" were assessed by assessors within each of four evaluation days, each containing three samples of different muscles from the same individual. Applied sensory descriptors were juiciness, tenderness, odour intensity, flavour intensity, fibrosity and chewiness. An unstructured 100 mm long scale which was transformed to a numerical scale (0 very low intensity- 100 very intensive) for calculation purposes was used for the evaluation.

The measured data were evaluated in the SAS statistical program using a mixed linear model (MIXED procedure). When evaluating the muscle chemical composition, the sex and muscle were included as fixed effects as well as the interaction of these effects. The day of slaughter and animal were included as random effects in the model. In addition, the random effects of the assessment day and the assessor were included into the model for sensory analysis. The statistical significance of the differences within the muscles was tested by the Tukey-Kramer test.

3. Results and discussion

Physical and chemical properties data are presented in table 1. The pH and the lightness ($L*$) values were significantly highest in RA muscle. TB was the most reddish muscle while LL had the lowest intensity of redness. There were no differences in yellowness between muscles. Differences in physical properties between muscles can be explained by different characteristics of muscle fibres and their different metabolic activity. While the LL and TB muscles belong to the glycolytic muscles, RA is referred to as an oxidative muscle[6].As can be seen from table 1, LL exhibited the lowest shear force value whereas RA the highest. This could be related to the chemical composition where statistical differences were also observed. LL muscle contained the lowest total and soluble collagen contents while TB the highest. RA had the highest content of intramuscular fat while TB the lowest one. Shear force is usually associated with sensory properties[4]. The lower is shear force, the higher juiciness, tenderness and chewiness is usually measured. Although RA had the lowest instrumental toughness

value, it scored the highest for sensory juiciness. This could be related to its highest intramuscular fat content[10].

Table 1. Physical and chemical properties of LL, TB and RA muscles from Fleckvieh cattle.

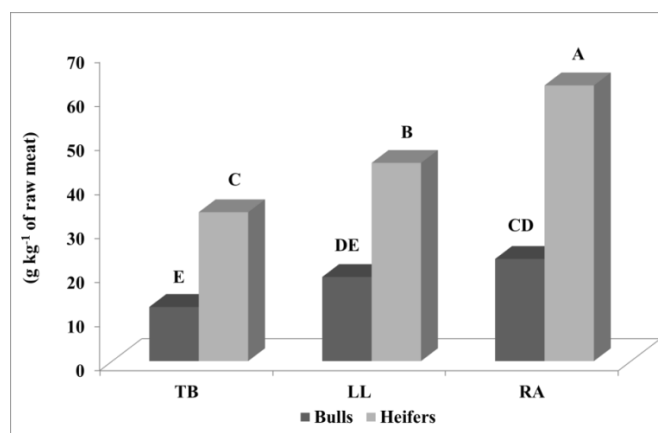|	Muscle			Sex		Significance	
	LL	TB	RA	Bulls	Heifer	*P* -value	
	LSM	*LSM*	*LSM*	*LSM*	*LSM*	Muscle	Sex
pH_{48}	5.5 B	5.5 B	5.6 A	5.5	5.5	<0.001	0.833
Colour *L**(lightness)	39.3 B	38.9 B	41.6 A	40.4	39.5	0.001	0.272
Colour*a**(redness)	14.0 B	16.8 A	15.7 AB	15.0	16.0	0.001	0.188
Colour *b**(yellowness)	14.0	14.6	15.1	14.5	14.6	0.335	0.778
WB shear force[N]	40.6 C	49.2 B	56.4 A	50.3	47.1	<0.001	0.348
Dry matter	269.7 A	246.8 B	265.0 A	245.7	275.3	<0.001	<0.001
Protein	219.0	204.1	204.5	208.0	210.4	<0.001	0.401
Intramuscular fat	32.0 B	22.9 C	43.1 A	18.2	47.1	<0.001	<0.001
Hydroxyproline	0.5 C	0.8 A	0.7 B	0.7	0.6	<0.001	<0.001
Total collagen	3.3 C	5.4 A	4.1 B	4.6	3.9	<0.001	0.003
Soluble collagen [%]	29.0 B	33.8 A	31.8 AB	29.9	33.2	0.049	0.053

A, B,C values for muscles marked with different superscripts differ statistically (*p*< 0.05)
[a]*longissimus lumborum*
[b]*triceps brachii*
[c]*rectus abdominis*

The magnitude of differences between bulls and heifers within the physical properties of meat was rather negligible. However, considerable differences were observed in chemical composition. The meat from heifers contained significantly more dry matter, protein, intramuscular fat and less total collagen. Figure 1 allows comparing the intramuscular fat content of the assessed muscles in bulls and heifers expressed in the unit g kg^{-1} of raw meat. The lowest proportion was found in TB, while the highest amount was characteristic for RA. Compared to bulls, heifers had more than two fold higher intramuscular fat contents in all muscles; it was even 2.7 fold more in RA.

A,B,C,D,E values marked differently differ statistically from another (p< 0.05)

Figure 1. Intramuscular fat content of three muscles from bulls and heifers.

Figure 2 shows the results of the sensory profile for the three muscles regardless the sex of animals. Meat from LL had the highest score for tenderness, fibrosity and chewiness. TB samples had the highest odour and flavour intensity score, while the highest juiciness score was observed in RA probably because of the highest content of intramuscular fat which is known to influence meat flavour, juiciness and tenderness[11].Also the shear-force and the content of collagen influenced meat quality, the samples with higher content of total collagen and higher proportion of thermally insoluble collagen had a low score for tenderness[7]. These findings are in agreement with our results. Although the highest shear force value was measured in RA, it was tenderer than TB. It could be associated with the highest intramuscular fat content[10].
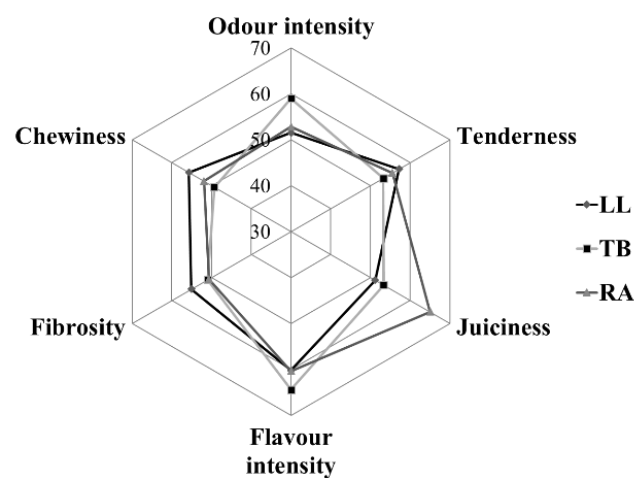

Figure 2. Sensory profile for the three muscles regardless the sex of animals.

As shown in Figure 3, it is clear that, except for the odour intensity, the meat from heifers was assessed by the sensory panel as more favourable for all the remaining sensory characteristics assessed. All these differences were statistically significant. As mentioned in many studies, the sensory characteristics of beef are influenced by the content of intramuscular fat, especially if these differences are significant [12,13].
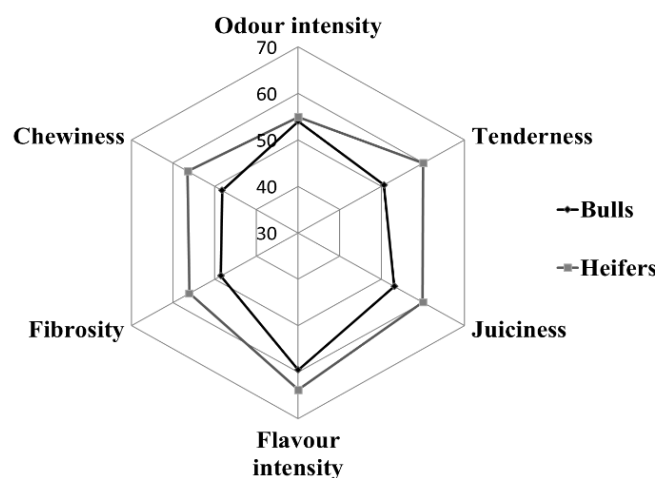

Figure 3. Sensory profile from bulls and heifers.

4. Conclusion

The relationships between sensory attributes and the content of intramuscular fat, total and soluble collagen were evaluated. Marked differences among muscles were detected in the content of intramuscular fat which positively influenced mainly juiciness of RA and several other sensory attributes. The highest score for tenderness and chewiness and the lowest shear force values were recorded in LL. Differences in the chemical composition and sensory profile of the three different muscles predetermine these parts for different culinary treatment so that their specific properties can be appropriately used. Compared to bulls, heifers had more than two fold higher intramuscular fat contents in all muscles; it was even 2.7 fold more in RA. This might be associated with significantly higher tenderness and chewiness observed in heifers. In addition, lower shear force values as well as lower total collagen contents and higher soluble collagen contents were observed in heifers. Thus, it confirmed the assumption of increasing meat tenderness associated with higher soluble collagen contents. Generally, the meat of heifers received higher scores in all the sensory attributes observed.

Acknowledgements

References

[1]   Bureš D, Bartoň L 2012a Growth performance, carcass traits and meat quality of bulls and heifers slaughtered at different ages*Czech J. Anim. Sci.***57** 34–43
[2]   Bartoň L, Teslík V, Zahrádková R, Bureš D 2003 Growth, feed efficiency and carcass characteristics of Czech Pied and Holstein bulls *Czech J. Anim. Sci.***48**172–178
[3]   Bartoň L, Bureš D, Kudrna V 2010 Meat quality and fatty acid profile of the musculus longissimus lumborum in Czech Fleckvieh, Charolais and Charolais × Czech Fleckvieh bulls fed different types of silages *Czech J. Ani. Sci.***55** 172–178
[4]   Bureš D, Bartoň L 2012b The chemical composition and sensory characteristics of meat from Aberdeen Angus, Gascon, Holstein and Czech Fleckvieh bulls *Maso Intern.***22** (2) 125–130
[5]   Torrescano G, Sánchez-Escalante A, Giménez B, Roncáles P, Beltrán J A 2003 Shear values of raw sample for 14 bovine muscles and thein relation to muscle collagen characteristics *Meat Sci.* **64**85–91
[6]   Oury M.P., Dumont R, Jurie C, Hocquette J F, Picard B 2010 Specific fibre composition and metabolism of the rectus abdominis muscle of bovine Charolais cattle*BMC Biochem.***11** 147–2091
[7]   Hocquette J F, Van Wezelmael L, Chriki S, Legrand I, Verbeke W,Farmer L, Scollan N D, Polkinghorne R, Rodbotten R, Allen P, Pethick D W 2014 Modelling of beef sensory quality for a better prediction of palatability*Meat Sci***97** 316–322
[8]   Bergman I, Loxley R 1963Two Improved and Simplified Methods for the Spectrophotometric Determination of Hydroxyproline*Anal. Chem.***35** (12) 1961–1965
[9]   Cross H R, Carpente Z L, Smith G C 1973 Effects of intramuscular collagen and elastin on bovine muscle tenderness*J. Food Sci.* **38** 998–1003
[10]   Corbin C H, O'Quinn T G, Garmyn A J, Legako J. F, Hunt M R, Dinh T T N, Miller M F 2015 Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments*Meat Sci.***100** 24–31
[11]   Wood J D, Enser M, Fisher AV, Nute G R, Sheard P R, Richardson R I, Hughes S I,

Whittington, F M 2008 Fat deposition, fatty acid composition and meat quality: A review*Meat Sci.***78** 343–358

[12] Hocquette J F, Gondret F, Baéza E, Médale F, Jurie C P, Pethick D W 2010 Intramuscular fat content in meat-producing animals: development, genetic and nutritional control, and identification of putative markers*Animal***4**303–319

[13] Gagaoua M, Trelouw E M C, Micol D, Hocquette J F, Moloney A P,Nuerneberg K, Picard B 2016 Sensory quality of meat from eightdifferent types of cattle in relation with their biochemical characteristics *J. Integr. Agric.***15** 1550–1563