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THE FACTORS INFLUENCING BEEF QUALITY IN BULLS, HEIFERS AND STEERS

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ABSTRACT

In the present study the biological factors which affect the nutritional and technological parameters and tenderness of beef were evaluated. We evaluated the effect of nutrition, commercial type, age of the animals at slaughter, carcass weight, net gains, duration of beef ageing and the class of meatiness and fat content in bulls, heifers and steers. For the experiment we chose animals at the end of the grazing period when they were weaned. The animals were fattened in the stable and divided into 3 groups (each group was represented by bulls, heifers and steers) based on the type of the feed ration: 1st group: maize silage, clover-grass silage, meadow hay and concentrates; 2nd group: maize silage, meadow hay, concentrates and urea; 3rd group: in winter the animals were fed clover-grass silage, from the end of April they grazed. Significant ($P < 0.05$) differences were revealed between the categories of cattle in the content of intramuscular fat, water holding capacity, meat colour, cooking loss, and meat tenderness. While evaluating the factors of animal nutrition, commercial type and carcass weight showed highly significant differences ($P < 0.01$) in the content of total protein and intramuscular fat in the meat. The technological properties of the meat were dependent ($P < 0.01$) on the type of the feed ration and on the commercial type, but they were also affected by the animal's age at slaughter and duration of beef ageing which are the most important factors affecting the tenderness of meat.

Key words: cattle, beef; nutritional parameters; technological parameters; tenderness of meat; ageing of meat

INTRODUCTION

The top priority of every breeder should be the high quality of foodstuffs, or the production of high-quality and safe animal-based foodstuffs. The resulting nutritional, technological, sensory and culinary meat quality is dependent on a number of factors. Šubrt and Schmidt (1994) evaluated the nutritional and technological quality of meat of bulls and heifers. Compared to heifers the authors found a lower proportion of dry matter in the musculature of the bulls (25.40 % and 24.57 %, respectively). However, the proportion of total protein was comparable (21.78–21.98 %). The proportion of intramuscular fat of heifers was higher by 0.82 % (2.63 %). The average pH_{48} value of bulls and heifers was 5.6 and 6.16, respectively. The bulls had a higher content of muscle pigment than heifers (2.42 $mg.g^{-1}$ and 1.72 $mg.g^{-1}$, respectively). The water holding capacity was similar in both sexes, ranging between 90–92 %. Page *et al.* (2001) evaluated the effect of sex and breed on beef quality. They reported a very high correlation between the pH value and meat colour, or colour spectra L*, a*, b*. In the meat of cattle slaughtered at the age of 498 ± 38 days, Žgur *et al.* (2003) found 4.13 % of intramuscular fat and a pH value ranging around 5.67. The colour of meat was evaluated on the basis of colour spectra (L* = 38.6; a* = 21; b* = 11.5). Sochor *et a*l. (2005) compared the quality of beef of Bohemian spotted cattle and its hybrids, with Charolais, beef Simmental and Aquitaine Blond cattle. In the MLLT

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samples we evaluated the dry matter content, proportion of total protein, intramuscular fat and ash content. The authors found no significant (P>0.001) differences in these parameters among the commercial breeds. Statistically significant (P<0.001) differences were discovered in the water holding capacity between C x Ch; C x Ba; C x Si and in the size of the MLLT area between hybrids Ch x Ba; C x Si; C x Ba. Farouk and Wieliczko (2003) explored the effect of nutrition and duration of ageing of the meat of steers. The authors compared the quality of meat of steers raised on pasture and steers fattened in the stable. Differences (P < 0.01) in the mode of fattening appeared only in the pH value (pasture 5.61, stable 5.55) and in the proportion of the red spectrum "a*" of the meat colour in favour of animals fattened in the stable. The protein content was identical in both groups (16.3 %). The water holding capacity was insignificantly higher in the grazing animals (55.7 > 52.8 %). Sami *et al*. (2004) compared the qualitative parameters of meat of Simmental bulls under extensive and intensive breeding. Under intensive breeding the carcass weight was higher by 35 kg on an average (358 kg). The pH value was balanced in both groups. The water drip loss was 1.30 and 1.02 %, respectively. During grilling the weight loss ranged around 24.2-24.3 %. The values of the colour spectra (L*; a*; b*) of the animals were balanced. The content of intramuscular fat was higher in the meat of intensively fattened animals (2.28 %). On the other hand, Cerdeno *et al.* (2006) did not find any effect of the intensity of bull nutrition on the level of nutritional parameters of beef. A very important parameter of the quality of meat is tenderness. It is directly related to the customer's preference, which kind of meat is more suitable as fast food, if the bit is tender to the bite and sufficiently juicy. Tenderness of meat is a sensory method of evaluating the meat quality which can be evaluated on the basis of the resistance of the meat in shear force tests. After slaughter, owing to degradation of muscle glycogen, the pH value drops approximately to 5.5 and the coupling of actin and myosin filaments cause rigor mortis. For the tough meat to be edible again it must be stored under the required physical, technological and hygienic conditions for an optimal period of time. Monsón *et al*. (2004) published results of evaluations of the quality of the carcass and meat of Holstein, Limousine, Aquitaine Blond and Swiss Brown bulls. The animals were slaughtered at the age of 13–15 months, having weights of 505 (H) to 617 kg (Ba). In order to cut through the muscle fibres of meat aged for 14-days a force of 4.37 – 4.99 N/cm^2 was necessary. Sochor *et al.* (2005) evaluated the tenderness of boiled meat. The cooking loss of meat of the C breed and C x Ch, C x Ba, C x Si crossbreds were 23 % and 28.74–30.31 %, respectively. Concerning the shear force tests with boiled meat, ranging between 84.58 N (C) and 119.95 N (C x Ba), the authors noted significant differences (P < 0.01) between C x Ch – C x Ba; C – C x Ba, the values being with in the range of 86.63–119.95 and 84.58–119.95 N, respectively. From muscle compaction tests (TPA_1 and TPA_2) statistically significant differences (P < 0.05) were reported between the Bohemian Spotted cattle (TPA_1 – 161.62 N/cm^{-2}, TPA_2 – 142.56 N/cm^{-2}) and the hybrid C x Ch (TPA_1 – 239.39 N/cm^{-2}, TPA_2 – 210.84 N/cm^{-2}) and C x Si (TPA_1 – 236.96 N/cm^{-2}, TPA_2 – 202.22 N/cm^{-2}).

MATERIAL AND METHODS

A group of 108 animals (36 bulls, 36 heifers and 36 steers) was used for the evaluations. A trio of animals (bull, heifer and steer) had a common father and they were born in the same week. Animals were crossbreeds of the Czech Fleckvieh (mother position), the Charollais, the Simmental (beef type) and hybrid bulls 50Ch25C25A and 50MS12,5H12,5Sh25Ch.

For the experiment we chose animals at the end of the grazing period when they were weaned. Animal age was 7-8 months. At this time the steers were castrated using a bloodless method. The animals were fattened in the stable and divided into 3 groups (each group was represented by bulls, heifers and steers) based on the type of the feed ration:

1st group: maize silage - 60% KD (0.078 kg NL, 6.18 J NEV), clover-grass silage - 10 % KD (0.1506 kg NL, 5.6 MJ NEV), meadow hay - 10% KD (0.102 kg NL, 5.1 MJ NEV) and concentrates S-1 - 20% KD.

2nd group: maize silage - 60% KD, meadow hay - 10% KD, concentrates S-1 - 20% KD and urea at a dose of 0.03 kg/100 kg body mass.

3rd group: in winter the animals were fed clover-grass silage, from the end of April they grazed, pasture loading was 2.15 animal per 1 ha.

The bulls and heifers were slaughtered at an average age of 650 ± 50 days. The slaughter age of the steers was 656 ± 45 days. The weight of the bulls' carcasses ranged between 314 and 454 kg. The average weight of the carcasses of heifers and steers ranged between 321 ± 41 kg and 334 ± 43 kg, respectively. The net gains of the bulls, heifers and steers was respectively 0.60 ± 135 $kg.day^{-1}$, 0.497 ± 74 $kg.day^{-1}$ and 0.512 ± 82 $kg.day^{-1}$.

Slaughter and technological analyses were carried out according to the Czech standard ČSN 46 61 20. Within 24 hours of slaughter the carcasses were cut, MLLT samples were taken from the right half and they were vacuum-packed and stored to age in a cooler with forced air circulation at a temperature of 2şC and relative humidity of 75%. The samples were analysed in the laboratory 48 hours after slaughter and after 2, 4 and 6 weeks of ageing. Kjeldahl's method was used to determine the proportion of total protein. Extraction of intramuscular fat was done with ether on an extraction extension of Soxhlet's apparatus. The technological parameters assessed was the water holding capacity and colour of meat which was evaluated by means of the proportion of the individual colour spectra (L*, a*, b*) using the MINOLTA CD-2600d photospectrometer [L* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness; (positive values = yellow, negative values = blue)]. At the same time, the colour was evaluated by reflectance (at 522 nm wavelength) and the content of muscle pigments (Hornsey, 1956). Part of the colour evaluation was assessment of the pH value of the meat which greatly affects the meat colour. Tenderness of the meat was evaluated according to the method of Christensen *et al*. (2000). The meat samples were left in the water bath in a way maintaining the internal temperature of the sample above 70ş C for 1 hour. The following toughness of the sample was characterised by shear force and resistance to compression (TPA_1, TPA_2) using the Warner-Bratzler equipment (WBSF). Statistical analysis of the tenderness of the meat was conducted by means of the statistical package SAS 9.1, by the GLM procedure – variance analysis with fixed effects:

$$Y_{ijklmnop} = \mu + KD_i + UT_j + V_k + H_l + N_m + Z_n + P_o + S_p + e_{ijklmnop}$$

where:

$Y_{ijlkmnop}$ – observed value of the quality parameters;

μ – average value of dependent variable;

KD_i – fixed effect: type of feed ration (1 – maize silage, clover-grass silage, hay, concentrates; 2 – maize silage, hay, concentrates, urea; 3 – clove-grass silage, pasture vegetation);

UT_j – fixed effect: commercial type (1 – C x Ch, 2 – C x Si, 3 – C x 50Ch25C25A, 4 – C x 50MS12,5H12,5Sh25Ch;

V_k – fixed effect: age of animal at slaughter (1 – to 620 days, 2 – 621 - 680 days, 3 – more than 681 days);

H_l – fixed effect: carcass weight (1 – do 320 kg, 2 – 321–370 kg, 3 – above 371 kg);

N_m – fixed effect: net gains (1 – to 0.50 kg.day^{-1}, 2 more than 0.501 kg.day^{-1});

Z_n – fixed effect: class of meatiness (1 – "U", 2 – "R");

P_o – fixed effect: class of fat content (1 – "1", 2 – "2", 3 – "3");

S_p – fixed effect: state of meat (1 – fresh, aged 2–2 weeks, aged 3–4 weeks, aged 4–6 weeks).

The fixed effects are based on evaluations of correlations between the evaluated parameters of meat quality and the effects mi and correlations between the fixed effects.

RESULTS AND DISCUSSION

We evaluated selected nutritional and technological parameters of quality and indicators responsible for the tenderness of beef. A number of factors act at the level of the individual quality parameters. We monitored bulls, heifers and steers and evaluated the effect of nutrition, commercial type, age of animal at slaughter and carcass weight. We also considered the level of net gains; the analysis also included results of the classification of carcasses in the SEUROP system because the result of this classification is to reflect the quality of the slaughter animal, or the meatiness and fat content, but it has not yet been defined whether this classification is related to beef quality. The last but not the least important factor which was incorporated into the analysis was the duration of beef ageing. Table 1 gives the results of statistical processing, or the result of the analysis of variance. Determination coefficients (R^2) expressing the information status of the statistical model are relatively high, ranging between 59 % and 99 %. We can therefore conclude that the selected effects have a crucial effect on the level of the individual qualitative parameters and differences between the cattle's sex are evident when a lower level of R^2 was noted while evaluating the quality of the meat of bulls. By contrast the determination coefficient reached the highest values for the qualitative parameters of the meat of heifers. In terms of the nutritional parameters we evaluated the proportion of intramuscular fat and protein content. In the meat of bulls the content of intramuscular fat was 1.29 % ± 0.45 %. The fat content of the meat of heifers was higher (4.39 ± 2.36 %). The proportion of intramuscular fat of steers was 2.88 ± 1.51 %. The differences in this qualitative parameter among heifers, bulls and steers were highly significant ($P < 0.01$). Chládek and Ingr (2003) noted lower amounts of intramuscular fat (2.00 %) in the meat of steers. The total protein content in the respective categories of cattle was relatively constant; in bulls, heifers and steers it was Y= 21.4 %, 21.13 % and 21.26 %, respectively. Šubrt *et al*. (2002) reported that the proportion of total protein was 21.05 % in Bohemian Spotted cattle and 21.33 % in Charolais bulls. In terms of technological parameters we evaluated the water holding capacity (an important parameter for producers of meat products), pH value and colour of meat (important parameter of quality for the consumer). The water holding capacity was the highest in the meat of steers and heifers (Y = 83.38 and 83.27 %, respectively). The water holding capacity of the meat of bulls was lower by an order of 2 % (Y = 81.3 %). The differences in the water holding capacity between the bulls and the other categories of cattle were significant ($P<0.05$). The pH value was relatively balanced and ranged between 5.50 (heifers) and 5.54 (bulls). The pH value is much more affected by stress and exhaustion

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Table 1: The results of analyses of variance for bulls, heifers and steers

Quality parameter	Bull (n=36)			Heifer (n=36)			Steer (n=36)			Sign.
	$Y_{ijklmnop}$	s_x	R^2	$Y_{ijklmnop}$	s_x	R^2	$Y_{ijklmnop}$	s_x	R^2	
Total protein (%)	21.4	0.61	0.65	21.13	0.75	0.93	21.26	0.62	0.74	ns
Intramuscular fat (%)	1.29	0.45	0.59	4.39	2.36	0.94	2.88	1.51	0.89	**
Water holding capacity (%)	81.3	4.12	0.79	83.27	4.44	0.94	83.38	5.08	0.82	*
pH	5.54	0.07	0.79	5.50	0.06	0.88	5.51	0.07	0.84	ns
Muscle pigments ($mg.g^{-1}$)	4.14	0.60	0.61	3.89	0.75	0.85	4.05	0.62	0.79	*
Reflectance (%)	5.38	1.32	0.67	5.84	1.56	0.84	5.17	1.45	0.82	**
L*	36.8	2.27	0.85	38.67	2.66	0.89	37.46	2.62	0.89	**
a*	12.5	2.07	0.72	12.52	2.03	0.96	12.53	1.97	0.73	-
b*	10.0	1.91	0.81	11.05	1.79	0.96	10.28	1.86	0.79	-
Cooking loss (%)	31.7	5.2	0.89	28.50	3.71	0.90	30.06	4.19	0.89	*
WB shear force (kg)	9.726	3.948	0.92	7.726	3.362	0.97	8.276	3.753	0.88	*
TPA_1 (1^{st} compression) (kg/cm^2)	31.009	10.228	0.72	26.825	8.263	0.81	28.697	9.722	0.63	*
TPA_2 (2^{nd} compression) (kg/cm^2)	25.473	8.859	0.63	22.110	8.531	0.99	23.855	8.241	0.62	-

ns = no significant differences (P>0.05); * significant differences (P<0.05); ** = significant differences (P<0.01)

of the animals before slaughter than by the factors we explored. Šimek *et al*. (2003) monitored changes in the pH value of bulls in regular intervals from slaughter and they found comparable values of pH_{48} (5.60). The colour of beef was evaluated using several methods; the content of muscle pigments, reflectance and proportion of colour spectra. The content of muscle pigments in beef had a downward tendency: bulls > steers > heifers, 4.14 > 4.05 > 3.89 $mg.g^{-1}$, respectively, with significant (P<0.05) differences in the content of pigments between bulls and heifers. The results in the content of muscle pigments of the individual categories of cattle fully correspond with the results of reflectance. The reflectance was the highest in the meat of heifers which had the lowest content of muscle pigments (Y = 5.84 %). The meat of bulls and steers was darker and reflectance was respectively 5.38 and 5.17 %. Exploring the proportion of colour spectra the meat of heifers was found to be the lightest (L* = 38.67) and the meat of bulls the darkest (L* = 36.8 %). The light colour of the meat is closely associated with the amount of intramuscular fat which was the lowest in this category of cattle. The proportion of the red spectrum (a*) of the individual categories was identical (B – 12.50; H – 12.52; S – 12.53). The proportion of yellowness (b*) ranged between 10.00 (bulls) and 11.05 (heifers). Žgur *et al.* (2003) and Gill *et al*. (2008) monitored comparable values of the "L*" and "b*" colour spectrum. When evaluating the tenderness of beef we took into account the weight loss due to the cooking temperature. Loss of weight was the highest in the meat of bulls (Y = 31.70 ± 5.2 %), lower in the meat of steers (Y = 30.06 ± 4.19 %) and the lowest in the meat of heifers during cooking (Y = 28.50 ± 3.71 %). Georgie-Evins *et al*. (2004) reported similar weight losses due to cooking temperature ranging between 29.8 % (fresh meat) and 31.3 % (meat aged for a period of 14 days). The tenderness of meat was based on results of shear and pressure tests. The shear force of the meat of bulls, heifers and steers was 9.726 kg, 7.726 kg and 8.276 kg, respectively. Sochor *et al.* (2005) published comparable shear force values for Charolais (8.663 kg) and Bohemian Spotted (8.458 kg) bulls. Özlütürk *et al*. (2004) reported a slightly lower shear force values (7.14 kg). Huffman *et al.* (1996) discovered that a force of 3.5 to 5.6 kg suffices to cut the muscle fibres of beef; this is considerably less than what we discovered. Beef that was most resistant to muscle fibre cutting was also the most difficult to compress and mince (TPA_1 = 31.009 kg/cm^2, TPA_2 = 25.483 kg/cm^2). The meat of heifers had the highest content of intramuscular fat and was most tender. A force of 7.726 kg was required to cut the muscle fibres and 26.825 kg/cm^2 (TPA_1) and 22.110 kg/cm^2 (TPA_2) to compress and mince. The values for steer meat were

TPA_1 = 28.625; TPA_2 = 23.855 kg/cm^2. Significant differences (P < 0.05) in shear force values and TPA_1 were found between the meat of bulls and heifers. Ahnström *et al.* (2006) reported that the shear force differed in beef from the left (6.77 kg) and right (5.33 kg/cm^2) halves of the bull carcass.

Table 2 gives the evaluation of the effect of the individual factors on qualitative parameters of the meat of bulls. The type of the feed ration had a highly significant (P < 0.01) effect on the amount of intramuscular fat, proportion of total protein, water holding capacity of the meat and pH value of the meat. Nutrition of the bulls also had a significant (P < 0.01) effect on the colour of meat (reflectance and L*, a*, b*), cooking loss and shear force required to cut and mince the meat. The commercial type had a highly significant (P < 0.01) effect on the proportion of intramuscular fat, pH value, colour (except for a*) and tenderness of meat. The dependence of the water holding capacity and TPA_2 on the commercial type was also noticed (P < 0.05). Šubrt and Mikšík (2002) proved that the effect of the commercial type on the content of muscle fibres was identical, insignificant (P > 0.05), but contrary to our results the authors did not prove the effect of the commercial type on the water holding capacity. Selecting the optimal age of the animals is decisive (P < 0.01) for the content of intramuscular fat, pH value, reflectance, colour spectrum L*, a*, b*, cooking loss, shear force and resistance of the meat to mincing. The effect of the slaughter age on the proportion of proteins and pigments in beef was insignificant. The correlation between the weight of the animal, or weight of the carcass, and the evaluated parameters, with the exception of the content of muscle pigments, was very close (P < 0.01). The results were similar also in terms of net daily gains. The net gains had an insignificant (P>0.05) effect on the content of muscle pigments and water holding capacity. The class of meatiness had a significant effect (P < 0.01) on the monitored nutritional parameters and shear force of meat. Sami *et al.* (2004) did not prove that the class of meatiness affected the pH value of beef either. The fat content was closely (P < 0.01) connected with the content of protein and fat in the meat, with the lightness of meat (L*), cooking loss and shear force. The duration of beef ageing had an insignificant effect on the content of nutritional parameters; however, it had a great effect on the water holding capacity, on the pH value, proportion of the colour spectra, shear force and TPA_1.

Table 3 documents the effect of selected parameters on meat quality of heifers and Table 4 the same on steer beef. In both categories of cattle identical effects were detected for the factors on the qualitative parameters of beef. The nutrition of heifers and steers had a significant

Table 2: The effect of factors on beef quality of bulls

Quality parameter	Fattening	Commercial type	Age of animal at the time of slaughter	Weight of carcasses	Net daily gain	SEUROP composition	SEUROP fatness	Duration of ageing
Total protein (%)	**	ns	ns	**	*	**	**	ns
Intramuscular fat (%)	**	**	**	**	**	**	**	ns
Water holding capacity (%)	**	*	*	**	ns	ns	ns	**
pH	**	**	**	**	**	ns	*	**
Muscle pigments (mg.g^{-1})	ns	**	ns	ns	ns	*	ns	ns
Reflectance (%)	**	**	**	**	**	ns	ns	ns
L*	**	**	**	**	**	ns	**	**
a*	**	ns	**	**	**	ns	*	**
b*	**	**	**	**	**	*	*	**
Cooking loss (%)	**	**	**	**	**	ns	**	**
WB shear force (kg)	**	**	**	**	**	**	**	**
TPA_1 (1st compression) kg/cm^2)	**	**	**	**	**	ns	ns	**
TPA_2 (2nd compression) (kg/cm^2)	**	*	**	**	**	ns	ns	ns

ns = no significant differences (P>0.05); * significant differences (P<0.05); ** = significant differences (P<0.01)

Table 3: The effect of factors on beef quality of heifers

Quality parameter	Fattening	Commercial type	Age of animal at the time of slaughter	Weight of carcasses	Net daily gain	SEUROP composition	SEUROP fatness	Duration of ageing
Total protein (%)	**	**	*	**	ns	**	**	ns
Intramuscular fat (%)	**	**	ns	**	**	ns	**	ns
Water holding capacity (%)	**	**	*	*	**	ns	ns	**
pH	ns	ns	ns	ns	ns	**	*	**
Muscle pigments (mg.g^{-1})	**	**	*	ns	ns	ns	*	ns
Reflectance (%)	**	ns	*	*	**	*	ns	ns
L*	**	*	**	**	**	ns	ns	**
a*	**	**	**	ns	**	ns	*	**
b*	**	**	**	**	**	ns	*	**
Cooking loss (%)	**	ns	ns	ns	*	ns	*	**
WB shear force (kg)	**	ns	**	ns	ns	ns	ns	**
TPA_1 (1st compression) (kg/cm^2)	ns	ns	ns	ns	ns	ns	ns	ns
TPA_2 (2nd compression) (kg/cm^2)	**	**	**	**	**	**	**	**

ns = no significant differences (P>0.05); * significant differences (P<0.05); ** = significant differences (P<0.01)

Table 4: The effect of factors on beef quality of steers

Quality parameter	Fattening	Commercial type	Age of animal at the time of slaughter	Weight of carcasses	Net daily gain	SEUROP composition	SEUROP fatness	Duration of ageing
Total protein (%)	**	**	*	**	ns	ns	*	ns
Intramuscular fat (%)	**	**	ns	**	**	**	**	ns
Water holding capacity (%)	**	**	*	*	**	ns	**	**
pH	ns	ns	ns	ns	ns	ns	ns	**
Muscle pigments (mg.g^{-1})	**	**	*	ns	ns	**	ns	ns
Reflectance (%)	**	ns	*	*	**	*	*	ns
L*	**	*	**	**	**	ns	**	**
a*	**	**	**	ns	**	*	ns	**
b*	**	ns	**	**	**	*	*	**
Cooking loss (%)	**	ns	ns	ns	*	ns	**	**
WB shear force (kg)	**	ns	**	ns	ns	ns	**	**
TPA_1 (1st compression) (kg/cm^2)	ns	ns	ns	ns	ns	ns	ns	ns
TPA_2 (2nd compression) (kg/cm^2)	**	**	**	**	**	ns	ns	**

ns = no significant differences (P>0.05); * significant differences (P<0.05); ** = significant differences (P<0.01)

($P < 0.01$) effect on all the parameters with the exception of the pH value and TPA_1. Also, Bartoň *et al*. (2001) reported that nutrition affected the content of proteins and intramuscular fat in beef. In contrast, Moloney *et al*. (2008) did not show any significant effect of nutrition on the protein content in meat and Varela *et al*. (2004) reported an insignificant ($P > 0.05$) effect of the mode of fattening on the meat colour (L*, a*, b*) of steers. Similar results were confirmed while evaluating the effect of the commercial type; we noted an insignificant effect on the pH value, reflectance, cooking loss, shear force and TPA_1. Latimori *et al.* (2008) reported a significant ($P < 0.05$) effect of nutrition and breed on the colour and tenderness of meat. The slaughter age of steers and heifers had a highly significant ($P < 0.01$) effect on the tenderness of the meat (shear force and TPA_2) and on the proportion of the colour spectra (L*, a*, b*). The age of the animals at slaughter had a significant ($P < 0.05$) effect on the amount of muscle pigments and proteins, on the water holding capacity and reflectance. Similar to bulls the weight of heifers and steer carcasses were related to the content of protein and intramuscular fat. The correlations between the pH value, amount of muscle pigments, cooking loss, shear force and TPA_1 and the weight of heifer and steer carcasses were insignificant. The net gains were in very close ($P < 0.01$) correlation with the amount of intramuscular fat, water holding capacity, colour of meat evaluated as reflectance and the proportion of the colour spectra. Likewise, Frickh *et al*. (2002) reported significant ($P < 0.01$) effect of net gains on the amount of intramuscular fat. No significant ($P > 0.05$) correlations were detected between the class of meatiness and content of proteins, technological properties and tenderness of beef. The fat content correlated ($P > 0.01$) with the nutritional parameters, reflectance and colour of meat (L*), cooking losses and shear force. The duration of ageing of steer and heifer meat had an insignificant ($P > 0.05$) effect on the amount of intramuscular fat, total protein and muscle pigments. A highly significant ($P < 0.01$) correlation was discovered between the duration of ageing of meat of heifers and steers and the water holding capacity, pH value and proportion of the colour spectrum L*, a*, b*. Meat ageing also affected ($P < 0.01$) the cooking loss and the resistance of muscle fibres to cutting and mincing. Shackelford *et al*. (1997) reported a highly significant ($P < 0.01$) effect of the duration of ageing of heifer and steer meat on meat tenderness.

CONCLUSIONS

We can conclude that most of the monitored factors had a significant effect on the nutritional value (the highest total protein content in bulls was 21.4 %), technological properties (beef water retention in bulls was 81.3 %, in heifers was 83.27 % and in steers was 83.38 %) and tenderness of beef (the highest WB shear force of meat was 97.26 N in bull and the lowest 77.26 N in heifer. The content of total protein and intramuscular fat in the meat was dependent particularly ($P<0.01$) on animal nutrition, commercial type and on the weight of the animal at slaughter, or carcass weight. The technological properties of the meat were dependent on the type of the feed ration and commercial type; but were affected considerably more by the age of the animals at slaughter and the duration of beef ageing which is one of the most important factors positively effecting the tenderness of meat (together with nutrition, the commercial type, age and weight of the animals at slaughter and net gains). The correlation between the classification in the SEUROP system and meat quality was positive ($P>0.01$); the class of meatiness was correlated more with the nutritional parameters ($P>0.01$) and the fat content class rather reflected the technological quality and tenderness of beef.

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